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ABSTRACT

This atlas is a nontechnical presentation of the geography and history of world commercial nuclear power with particular emphasis on the United States. Neither pro- nor antinuclear, it presents commercial nuclear power data in a series of specially prepared, easily read maps, tables, and text. The first section (United States) includes information on: nuclear beginnings; second generation power plants; commercial nuclear power plants (1984); installed capacity of nuclear power plants (1984); power reactors under construction (1984); cancellation of power reactors (1984); projected capacity of nuclear power plants (1999); and non-power reactors (1984). The second section (the world) includes information for 1984 on world nuclear power and nuclear power in North America, South America, the Orient, Japan, and Europe. Additional maps and tables are included in appendices. The maps illustrate (for 1984) commercial nuclear power plants in Europe, the Orient, South America, Japan, and North America. The tables provide data on operating nuclear plants in the U.S. (1984), third generation reactors, nuclear power plants under construction (1984), and nuclear power plants in the U.S. (1999). (JN)

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AN ATLAS OF NUCLEAR ENERGY

*A Non-Technical World Portrait
of Commercial Nuclear Energy*

John M. Ball

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Cover Photo: The twin reactor Sequoyah Nuclear Power Plant is on Chickamauga Lake 20 miles northeast of Chattanooga, Tennessee and operated by the Tennessee Valley Authority. This plant began operating in 1981 after more than ten years in construction. Our appreciation to Ms. Diane C. Carruthers and the Atomic Industrial Forum, Inc. for providing us with this TVA photo.

AN ATLAS OF NUCLEAR ENERGY
***A Non-Technical World Portrait of Commercial Nuclear
Energy***
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FOREWORD

A few years ago we were developing a unit on energy as part of an environmental studies course offered by our department. One of the topics was the growth and diffusion of commercial nuclear energy and we searched for maps to help students see the origin and spread of this relatively new technology (after all, most of our students have never known a day when we did not have commercial nuclear reactors). Few maps were to be found, and those we did discover were designed for a different purpose, so we hastily made our own. The student response to these was favorable, and we speculated there might be a general interest in a series of maps on this topic. Then in 1983 our department obtained a small micro-computer with graphics software, conveniently interfaced with a multi-color plotter. This Atlas is one of the early projects undertaken and completed using our new technology.

We were fortunate to have the cooperation and interest of many people at Georgia State University while this Atlas was in preparation. We are grateful for the support given us by our Dean of Arts and Sciences, Dr. Clyde Faulkner, to our Department Chairman, Dr. Truman Hartshorn, who has offered encouragement throughout the project, and to our colleagues and students, many of whom have grown tired by now of hearing us talk about nuclear energy. We appreciate very much the help our Staff Cartographer, Mr. Frank Drago, gave us. Frank has that rare capacity of being interested and able to help just at the time when it is most needed. Without the support provided by these people it is unlikely that this Atlas would have been undertaken, let alone completed.

Most of the content and organizational decisions for this Atlas were made in a series of Monday afternoon meetings during the spring of 1984, attended by Dr. Dent, Ms. Coe and myself. Ms. Coe became the computer expert and supervised the production of all maps for this Atlas (except the cartogram), which was a considerable task. It involved first getting acquainted with the new computer system, digitizing various base maps for the new system, and then plotting the data. Most of the maps went through several editions before the three of us were satisfied, but never did we hear Ms. Coe complain about the hours spent in doing, and redoing maps. Instead, she grew with the project and her interest, commitment, and total dedication to the task and to each of us made this a rewarding experience.

There would be no Atlas had it not been for the early interest of Professor Borden Dent. He expressed this interest at a time he was burdened with numerous other tasks, but progressively gave more and more of his time and talent as the work progressed. He worked closely with Ms. Coe and each of the maps met his standards before we did a

final plot. His cartogram of World Nuclear Energy was produced especially for this Atlas, which is a mark of his creativity. But his influence is not only in the maps but throughout the Atlas in the form of ideas and suggestions on all matters of organization and content. Professor Dent deserves a special credit, not only for his contribution to this Atlas, but also because he understands group process, which helped the three of us to work together so effectively.

A final word. It is exhilarating to see the various pieces of this Atlas finally come together and take form. Each of us has looked forward to the day when it would be completed. It should be said, however, that we did not always reach consensus, and there were several times when my opinion prevailed. The collection of all statistical data, preparation of tables, and writing of commentaries was by me. Therefore it should be clear that errors, inconsistencies, or any other shortcomings of this Atlas are my responsibility and my responsibility alone. We would greatly appreciate criticism or suggestions that would help improve the quality of this Atlas which hopefully will appear in a revised and expanded edition.

John M. Ball
Atlanta, Georgia
June, 1984

INTRODUCTION

Nuclear power plants in the United States have names, like people, pets and political parties, (unlike airline flights and Interstate Highways which have numbers). The custom is a carry-over from earlier technologies when power companies gave names to their hydro and fossil fuel power plants. The public, however, had little need or interest in knowing the name of the local power plant so their names remained largely unknown. In recent years, however, nuclear power plants have been more and more in the news and some of their names have become as familiar as local sports heroes. Many people are now aware of nuclear power plants in their home state, whether operating or under construction, and with this increased awareness a curiosity develops about places beyond. Few have an idea, however, about the number or distribution of nuclear power plants in the United States, and even fewer have a sense of their development in other parts of the world. Nor do many people have an idea of which nations have made a large commitment to the development of nuclear power and what the distribution is within those nations. The principal goal of this Atlas is to help satisfy those curiosities, and that is the theme of all maps.

There are a few explanations we should make about this Atlas. First, construction on nuclear power plants is being completed, halted, delayed, and/or cancelled at such a pace it is impossible to feel confident that what is true in April will be true in May or June. The data used here are correct, to our best knowledge and belief, as of April, 1984. Next, there are numerous places in the text, tables, and maps where we refer to "capacity" of nuclear reactors and nuclear power plants. This refers to the rating assigned to a reactor or plant based on the amount of electricity it can generate. There are different methods used to identify this capacity (Design Electrical Rating, Nameplate Ratings, Gross Maximum Dependable Capacity, etc.), but in an effort to keep it simple we have used Net Maximum Dependable Capacity which is given in megawatts of electrical energy (abbreviated MWe). Throughout this Atlas we use megawatt as the common unit of electrical power which is simply one million watts (or one thousand kilowatts) of electrical energy. In 1979 one megawatt of electricity provided sufficient industrial and domestic energy (on the average) for approximately 400 people in the United States.¹

This Atlas does not tell everything about nuclear power plants, nor is that our purpose. It is a brief non-technical geography and history of world commercial nuclear power with particular emphasis on the United States. The spatial characteristics of nuclear power are shown in a series of computer-generated maps, all developed specifically for this

Atlas. The historical characteristics are developed largely by analysis of tables, which are included, and selected secondary sources. Most information presented in this Atlas is drawn from easily available technical publications very familiar to people in the nuclear industry but not so familiar to the average citizen. Examples of these include reports of the Nuclear Regulatory Commission, publications of the Atomic Industrial Forum, and journals such as *Nuclear News*, and *Nuclear Industry*.

Another goal we have is to avoid the emotional traps often associated with nuclear issues. We have no ax to grind. Our purpose is to present a mass of nuclear data in cartographic and tabular form, with a text that is mostly an interpretation and discussion of those two. We believe our presentation brings clarity to a topic about which there is a general interest but a shortage of spatial data that is easily accessible.

The principal contribution of this Atlas (like any Atlas) is in the maps. We are not aware that anything similar has been done before. Not only is this Atlas unique because it brings together a collection of maps on nuclear energy, but also because it represents how computer-generated thematic maps may be used for such an endeavor. The maps included here were designed on a CRT and final separated art produced on a small plotter. Photographic negatives were made directly from this art, thus no conventional cartographic production methods were used (with the exception of the cartogram and the name labels placed on two maps).

In preparing this set of thematic maps our goal was to make them clear and simple, thus we took the risk of assuming that people with an interest in this theme will either know or have access to the base map information (names of states, countries, bodies of water, islands, etc.). To provide the base map information that some might want would have added considerable complexity to each of the computer maps and thus, in our view, detract from the thematic data. We have departed from this policy on only the two maps showing the location, by name, of the operating nuclear plants in the United States, and the ones under construction. We felt this was especially useful in developing an awareness of plant names and their locations.

Another word of explanation should be made here. The maps showing installed capacity are called graduated or proportional symbol maps. The installed capacity at each plant is represented by a circle scaled to a class of values in the total array of capacity values. Five classes were selected to represent the whole array. To make all maps directly

¹ Bertrand Goldschmidt, *The Atomic Complex: A Worldwide Political History of Nuclear Energy*. LaGrange Park, Illinois: American Nuclear Society, 1982, p. 245.

comparable, the classes of values, and circle sizes, are identical for all of these maps in the Atlas, although on a particular map a given data class and its circle may be missing. It is possible, therefore, to compare maps directly and gain a better understanding of the total *distribution* of installed capacity. It may be pointed out also that the reader should not try to see individual values at places; look at the maps to see visual mass ("clumps" of circles) and how *all* the installed capacity is distributed over space.

A comment is in order about the Appendix. Here are some maps and tables that are integral to the Atlas, but which we felt should not be in the main body of the volume, either because they were too long (such as Tables 19 and 21) or because commentary was not necessary. The maps show more precise locations of nuclear plants than was possible on many of the capacity maps in the main body of the Atlas. Also, on the capacity maps some symbols are "hidden" under other symbols making it sometimes impossible to see exactly the number or location of nuclear power plants, whereas the maps in the Appendix show the location of all plants.

FIRST GENERATION POWER PLANTS 1953-1965



• One Reactor

0 500
Miles

One Plant in
Puerto Rico
Not Shown

NUCLEAR BEGINNINGS

The use of nuclear energy for the generation of electricity is a relatively new technology. Following World War II governments and scientists in the United States and several European nations were devoting large amounts of time and money to nuclear research. In the United States much of the early research was by the Navy under the direction of Commander Rickover, the hope being that nuclear reactors could be used to power submarines. In 1949, however, a site was selected in Idaho to build a land-based plant for the generation of electricity, using a small experimental reactor developed by the Navy, and in 1951, the world's first electricity from nuclear energy was produced at this plant. It was only 100 kilowatts but it was an important breakthrough. The Soviet Union, however, built the world's first real nuclear plant to produce electricity. This was the five megawatt station located at Obinsk (near Moscow) that began operating in 1954.¹

In 1953 the U.S. Government and the Duquesne Light Company of Pittsburgh, Pennsylvania, embarked on a joint-venture, using a submarine-type reactor, to build the first nuclear power plant in the United States. This 60 megawatt plant, located at Shippingport in western Pennsylvania, began producing electricity in 1957. Thus the total history of the commercial use of nuclear energy for the generation of electricity in the United States is only from the mid 1950's to the present.

The 1950's through the early 1960's was a time in the history of the nuclear power industry in which the future offered great promise. Reports circulated that electrical energy would be virtually free. Surely we were on the threshold of a new era. "The Atomic Age", when living and lifestyles would be radically different and vastly improved. It was during this first stage of the industry, which continued to about 1965 in the United States, that construction began on fourteen additional commercial nuclear plants, all of which were operating by 1966 (Table 1). The industry, however, was still in the developmental stage. Many of these "First Generation" reactors were experimental, largely or partially funded by the U.S. Atomic Energy Commission, and rather small. Also, most of these early plants were short-lived—six operated five or fewer years, and only three are still operating in 1984. Another thing about these early nuclear plants is that they were built quickly—three to four years was common, though some did require five or six. And most of them cost less than 50 million dollars (only one cost more than 100 million). These numbers would change drastically as the industry matured.

Table 1
FIRST GENERATION REACTORS

Name	Location	Construction Began	Operation Began	Capacity MWe
Shippingport	Pennsylvania	1953	1957	50
Dresden #1	Illinois	1955	1959	200
Indian Point #1	New York	1955	1962	270
Fermi	Michigan	1955	1963	61
Yankee	Massachusetts	1956	1960	175
Pathfinder	South Dakota	1957	1964	58
CVTR	South Carolina	1958	1963	17*
Peach Bottom	Pennsylvania	1958	1966	40
Plqua	Ohio	1958	1963	11
BONUS	Puerto Rico	1958	1964	16
Elk River	Minnesota	1958	1962	22*
Big Rock Point	Michigan	1959	1962	70
Humboldt Bay	California	1959	1962	68
Hallam	Nebraska	1959	1963	75
LaCross	Wisconsin	1961	1966	50

*Includes capacity added by fossil fueled superheaters

Source: The U.S. Atomic Energy commission, *The Nuclear Industry*, 1966. Washington, D.C.: U.S. Government Printing Office, 1967, p. 76.

The distribution of First Generation Nuclear Power Plants results more from the location of utility companies receptive to cooperative ventures with the Atomic Energy Commission than population or total energy consumption. With the exception of Pathfinder in South Dakota, Hallam in Nebraska, and Humboldt Bay in California, the plants were established in the eastern half of the nation, but no particular clustering is evident, even though the "midwest" is well represented. We will see that some clustering begins to develop as the industry matures.

¹ *Ibid.*, p. 260.

SECOND GENERATION POWER PLANTS 1962-1968



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SECOND GENERATION POWER PLANTS

Most of the First Generation Nuclear Reactors were "prototypes" that provided technological and economic data essential to the continued growth of this infant industry. The commercial power interests had been skeptical during the early years since they had little reliable evidence that this new technology was a sound economic venture. To help the industry through this developmental stage the federal government provided considerable financial and technical assistance.

By the early 1960s the knowledge gained was ready to be used. Many commercial power companies were finally confident that nuclear energy was economically viable and plans were made, orders placed, and construction projects begun on "Second Generation" reactors (Table 2). These differed from the First Generation primarily in size—all were more than 300 megawatt units and most were 500 or more. This stage reached its height in the middle 1960s when orders were placed or construction begun on twenty-seven reactors. It is noted that these generally required a year or two longer to build than the earlier ones, and they cost more, but considering the increased output, they were a bargain. There was much optimism about the future during this stage, and the power industry was making plans to take full advantage of the new technology.

The location of the second generation nuclear power plants tends to reinforce the pattern established by the earlier prototypes—that is, the Eastern half of the nation. Washington had a plant, there was a new one in California, as there were in Colorado, Iowa, and two in Nebraska, but the other twenty-one plants were either on or to the east of the Mississippi River. It is interesting to note there was no concentration centering on Chicago, nor do we see any particular regional groupings in the Southern part of the nation. Only in the Northeastern Seaboard does it appear that a clustering of nuclear power plants was emerging.

Third Generation Reactors are defined here as those which had a capacity of 800 or more Megawatts. All of these date from the mid-1960s to the late 1970s when construction began, and practically all construction starts since the mid-1960s have been on Third Generation Reactors. Only a partial listing is given here (Table 19, Appendix) of the first twenty-eight reactors of this class that were ordered. A comparison of Table 19 with Tables 1 and 2 vividly shows the changes in the industry since the early 1950s.

The decade of the 1960s was a time of great optimism when the large power utility companies were giving serious thought to shifting more and more to nuclear fuel for the generation of electricity. Commonwealth Edison of Chicago, the TVA, Consolidated Edison of New York,

Duke Power of North Carolina, Florida Power and Light, Carolina Power and Light, and others were in the forefront of this new era. The future seemed so positive, so certain, and so clear. Surely by the end of the century nuclear energy would be generating the electricity that most people used. But something happened along the way to disrupt that dream. A hint of the problem is shown in Table 18 by noting that two reactors are still not completed, and a third (Diablo Canyon #1) only started operating in 1984.

Table 2
SECOND GENERATION REACTORS

Name	Location	Construction Began	Operation Began	Capacity MWe
Connecticut Yankee	CT	1962	1967	575
Oyster Creek #1	NJ	1963	1969	530
Nine Mile Point	NY	1963	1969	500
San Onofre	CA	1963	1968	430
NPR	WA	1963	1966	790
Pilgrim	MA	1954	1971	654
Turkey Point #1	FL	1965	1971	652
Millstone #1	CT	1965	1970	652
Fort St. Vrain	CO	1965	1979	330
Glenn	NY	1965	1970	426
Monticello	MN	1966	1971	545
Fort Calhoun	NB	1966	1974	457
Vermont Yankee	VT	1966	1972	514
Point Beach #1	WI	1966	1970	497
Robinson #2	SC	1966	1970	700
Palisades	MI	1966	1971	700
Surry #1	VA	1966	1971	780
Surry #2	VA	1966	1971	780
Turkey Point #4	FL	1967	1972	652
Hatch #1	GA	1967	1973	786
Maine Yankee	ME	1967	1972	790
Cooper	NB	1967	1972	778
Prairie Island #1	MN	1967	1972	530
Prairie Island #2	MN	1967	1974	530
Point Beach #2	WI	1967	1972	497
Kewaunee	WI	1967	1974	527
Arnold	IA	1968	1975	545

Source: U.S. Atomic Energy Commission, *The Nuclear Industry, 1970*. Washington, D.C.: U.S. Government Printing Office, 1970, pp. 154-155, and *Nuclear News*, various dates.

COMMERCIAL NUCLEAR POWER PLANTS, 1984



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COMMERCIAL NUCLEAR POWER PLANTS, 1984

In early 1984 there are fifty-five nuclear power plants in the United States, using eighty-one reactors for the commercial generation of electricity (Table 18, Appendix). Three of these plants have three reactors, twenty have two reactors, and thirty-two have only one reactor. The Three Mile Island plant in Pennsylvania is included in the Table here, although it is not operating. Unit Two of that plant has been indefinitely shut down since the accident of March 28, 1979. The other reactor, Unit One, is separate from Unit Two, was not affected by the accident, was not damaged, but it was also shut down. A request to restart Unit One is under review and it will probably become operational again, thus it is included here.

Twenty-eight of the fifty states in the United States have one or more operating nuclear plants in 1984. Note that Colorado has the only commercial nuclear power plant in the sparsely populated region of the Great Plains, the Rocky Mountains, and the Inter-Mountain Basin and Plateau Country. Note also that most of the fifty-four nuclear plants are in the East, where twenty-two of the thirty-one states have one or more nuclear plants. It is perhaps not surprising that the energy-rich states of Louisiana, Kentucky, and West Virginia do not have a nuclear plant, but it might be surprising to see that neither does Indiana. Other eastern states where they are absent are Mississippi, Delaware, Rhode Island, and New Hampshire. By the end of this decade it is anticipated that Louisiana and Mississippi will join the majority, leaving only six states in the East without nuclear plants.

There are two other related spatial characteristics to be noted. One is that most of the nuclear plants are in three separate clusters, and the second is that all are located on water which is essential for cooling.

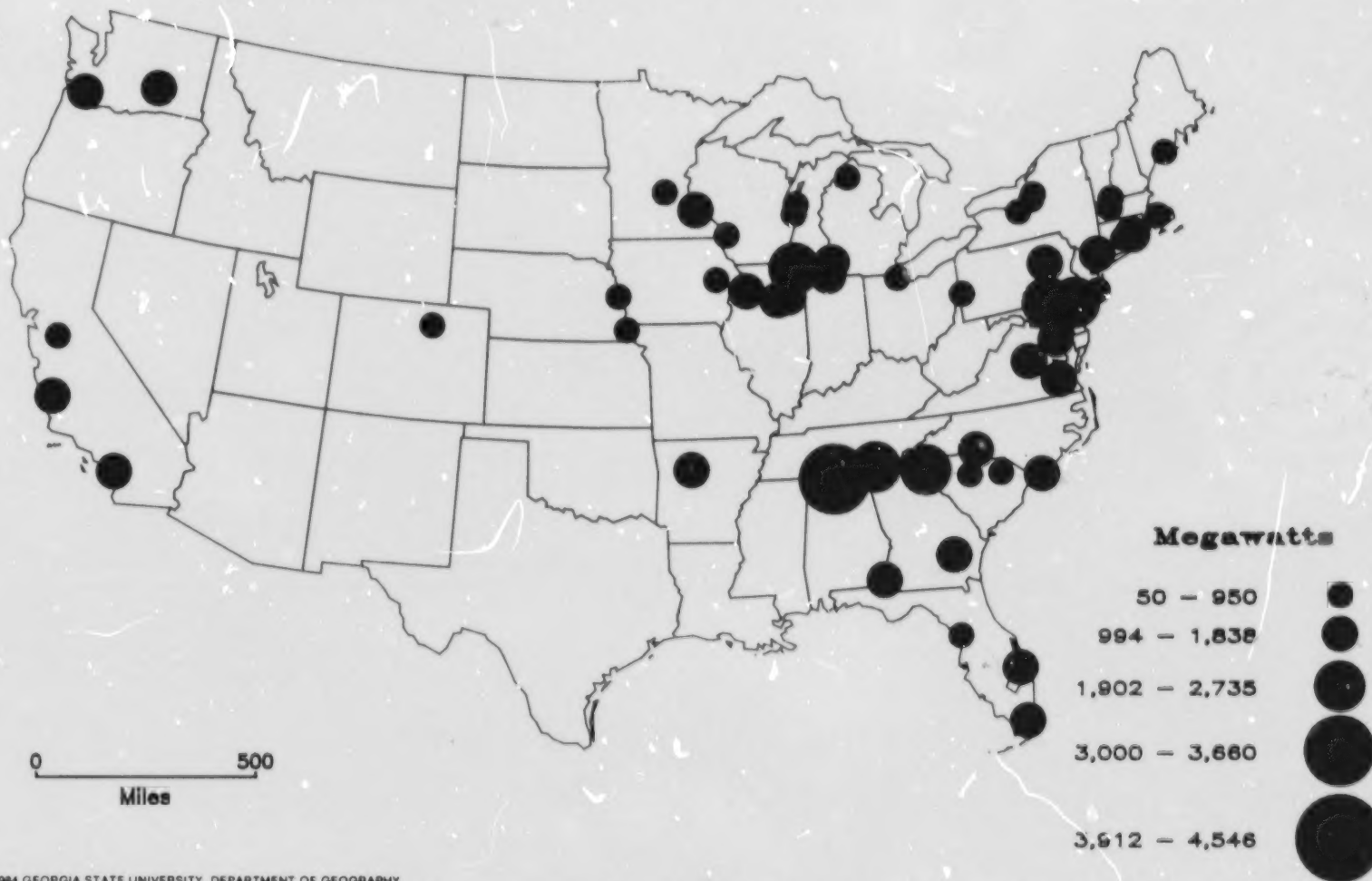
The nation's greatest concentration of commercial nuclear power is in the Megalopolis Nuclear Region. This is the Northeastern Seaboard and extends from north of Portland, Maine to Newport News, Virginia, and has the highest population densities in the nation. The region contains fifteen nuclear plants, twenty-three reactors, and accounts for approximately one-quarter of national commercial nuclear energy production. Many of these plants use ocean water for cooling, but others are on rivers which empty into the ocean, such as the Three Mile Island, Susquehanna, and Peach Bottom Plants which are all on the Susquehanna River in Pennsylvania (which empties into Chesapeake Bay).

The Chicago Nuclear Region is the most compact. It includes Southwestern Michigan and Northern Illinois and has five plants and eight reactors within 100 miles of Chicago. Access to water is again noted since three of these plants are on Lake Michigan, whereas the Dresden Plant is on the Kankakee River and the LaSalle Plant is near to the Illinois River.

The third nuclear region was a surprise to us. Unlike the other two it is not in an area of dense population but instead is astride a series of sparsely populated state borders—North and South Carolina, Georgia, Alabama, and Tennessee. This Southern Nuclear Region, the nation's second largest, has seven plants with fourteen reactors and accounts for 20% of the total national commercial electricity produced from nuclear energy. The Tennessee Valley Authority and Duke Power Company account for a majority of this production. They each operate two plants in the region, including Browns Ferry (TVA) and Oconee (Duke Power), the two largest nuclear plants in the nation.

These three nuclear regions account for more than half of the nuclear plants and the commercial nuclear energy production in the United States. And, it is not expected that the relative importance of these three regions will soon diminish, since in each there are additional reactors under construction which will add to their importance. In all remaining areas of the United States there are twenty-eight plants with thirty-six reactors which account for less than half of total national commercial energy produced from nuclear power.

INSTALLED CAPACITY OF COMMERCIAL NUCLEAR POWER PLANTS, 1984



INSTALLED CAPACITY OF NUCLEAR POWER PLANTS, 1984

There is great variation in the electrical generating capacity of nuclear plants in the United States. They range from the smallest, a single 50 megawatt reactor in Wisconsin to the three reactor, 3,195 megawatt plant in northern Alabama. In 1984 there are still more than a dozen first and second generation reactors operating in the nation, and since the older plants usually have less capacity than the newer ones, the location of power plants does not accurately portray the distribution of generating capacity.

Once again the three nuclear regions are evident, and each is dominated by a few large two or three reactor generating plants (represented by the larger circles). In the Chicago Nuclear Region there are three such plants (Cook, Zion, and Dresden), in the Megalopolis Nuclear Region there are seven (Salem, Peach Bottom, Indian Point, North Anna, Calvert Cliffs, Surry, and Millstone), and in the Southern Nuclear Region are three (Browns Ferry, Oconee, and Sequoyah). These thirteen plants account for only one-fifth of the commercial nuclear plants in the nation, but they generate almost one-half of the national electrical generating capacity from nuclear power. It will be seen that this concentration of nuclear generating capacity becomes even greater when reactors under construction are added to the map.

Outside the three nuclear regions plants are relatively small and widely dispersed. This distribution has changed very little in the past decade and we do not expect there will be significant change in the remaining years of this century.

Table 3
CHICAGO NUCLEAR REGION, 1984

Plant	State	Reactors	Capacity (MWe)
Cook	MI	2	2,130
Zion	IL	2	2,080
Dresden	IL	2	1,588
LaSalle	IL	1	1,078
Palisades	MI	1	805

Table 4
MEGALOPOLIS NUCLEAR REGION, 1984

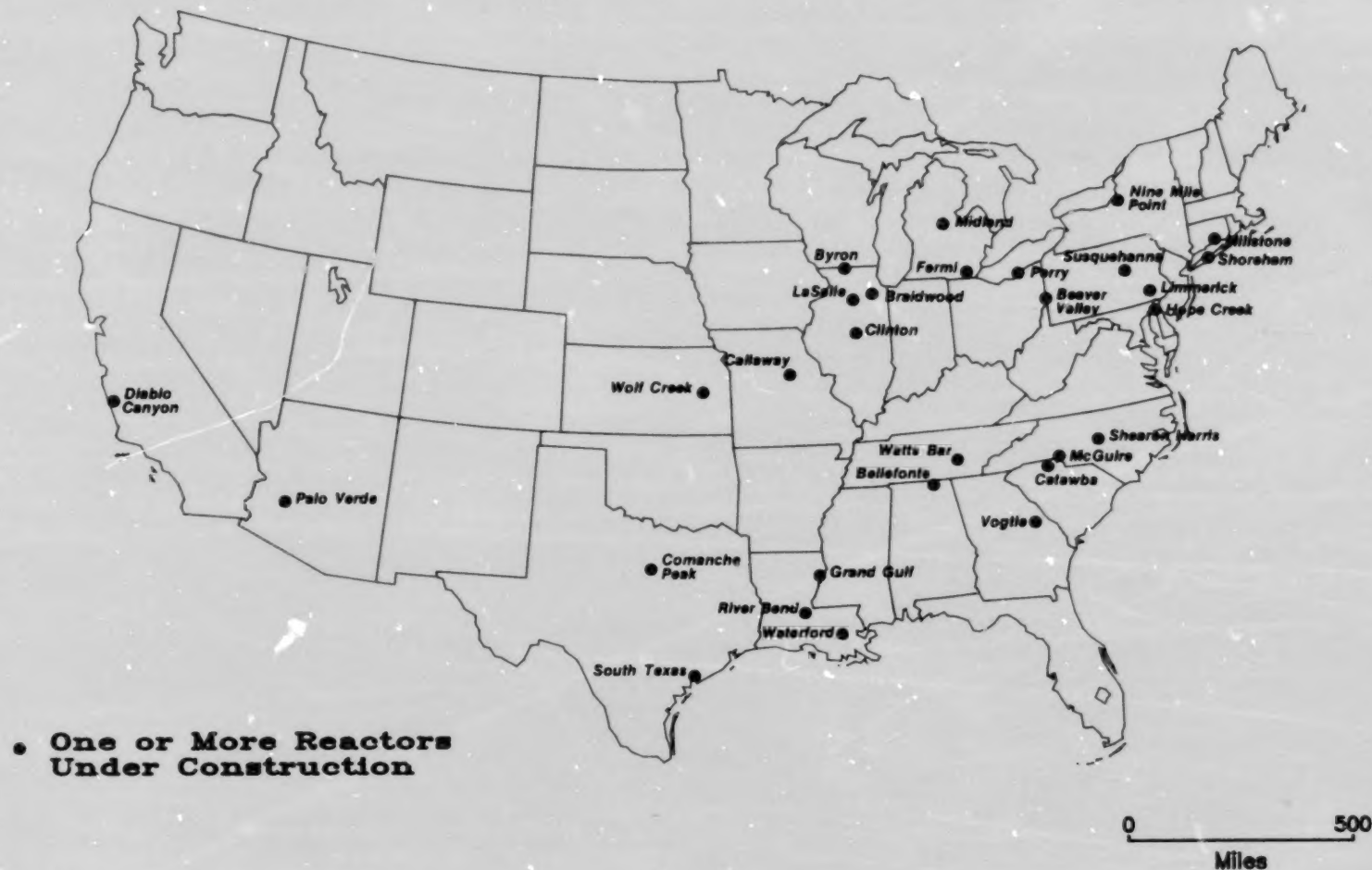
Plant	State	Reactors	Capacity (MWe)
Salem	NJ	2	2,305
Peach Bottom	PA	2	2,130
Indian Point	NY	2	1,838
North Anna	VA	2	1,814
Calvert Cliffs	MD	2	1,685
Surry	VA	2	1,576
Millstone	CT	2	1,530
Susquehanna	PA	1	1,065
Maine Yankee	ME	1	825
Three Mile Island	PA	1	819
Pilgrim	MA	1	655
Oyster Creek	NJ	1	650
Haddam Neck	CT	1	582
Vermont Yankee	VT	1	514
Yankee-Rowe	MA	1	175

Table 5
SOUTHERN NUCLEAR REGION, 1984

Plant	State	Reactors	Capacity (MWe)
Browns Ferry	AL	3	3,195
Oconee	SC	3	2,661
Sequoyah	TN	2	2,296
Brunswick	NC	2	1,642
McGuire	NC	1	1,180
Summer	SC	1	900
Robinson	SC	1	700

Source: Tables 3, 4, 5, compiled from Table 18

POWER REACTORS UNDER CONSTRUCTION, 1984



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POWER REACTORS UNDER CONSTRUCTION, 1984

In this section attention is given *only* to those power reactors which in 1984 were actually under construction. We therefore have excluded sixteen reactors, all of which had construction permits but on which construction was never begun or had been stopped either temporarily or indefinitely (Table 6). With this group excluded there are forty commercial power reactors at twenty-nine sites actively under construction in mid-1984 (Table 20, Appendix). Most of these are at or near completion, and as many as fourteen could begin commercial operation before the end of 1984¹.

Table 6
NUCLEAR PLANTS WHERE
CONSTRUCTION HAS STOPPED

Plant	State	Reactors	Capacity (MWe)
Yellow Creek	MS	2	2,570
Wash. Nuclear	WA	2	2,490
Hartsville	TN	2	2,466
Seabrook	NH	2	2,300
Marble Hill	IN	2	2,260
Carroll County	IL	2	2,240
Grand Gulf	MS	1	1,250
Limmerick #2	PA	1	1,055
Zimmer	OH	1	810
Midland #1	MI	1	425

Source: Various news reports during early 1984.

The location of nuclear power plants under construction tends to reinforce the regional clustering of operating plants. Note the four sites in the Chicago Nuclear Region (on which six reactors are being built), five sites in the Megalopolis Nuclear Region (one reactor each under construction) and in the Southern Nuclear Region (six sites and ten reactors under construction). These three regions account for more than half of all construction (twenty-one out of forty reactors on fifteen out of twenty-nine sites). The remaining sites are widely distributed with five on or near the three eastern-most Great Lakes, three in the lower Mississippi River Valley, four in the mid-section of the country, and three in the west. The eastern half of the nation continues to be the area with the greatest concentration of nuclear sites and nuclear reactors under construction.

Table 7
POWER REACTORS
UNDER CONSTRUCTION, 1984

	Number
90 — 100% Complete	18
80 — 89% Complete	7
70 — 79% Complete	4
60 — 69% Complete	5
50 — 59% Complete	3
Less than 50% Complete	3
Total	40

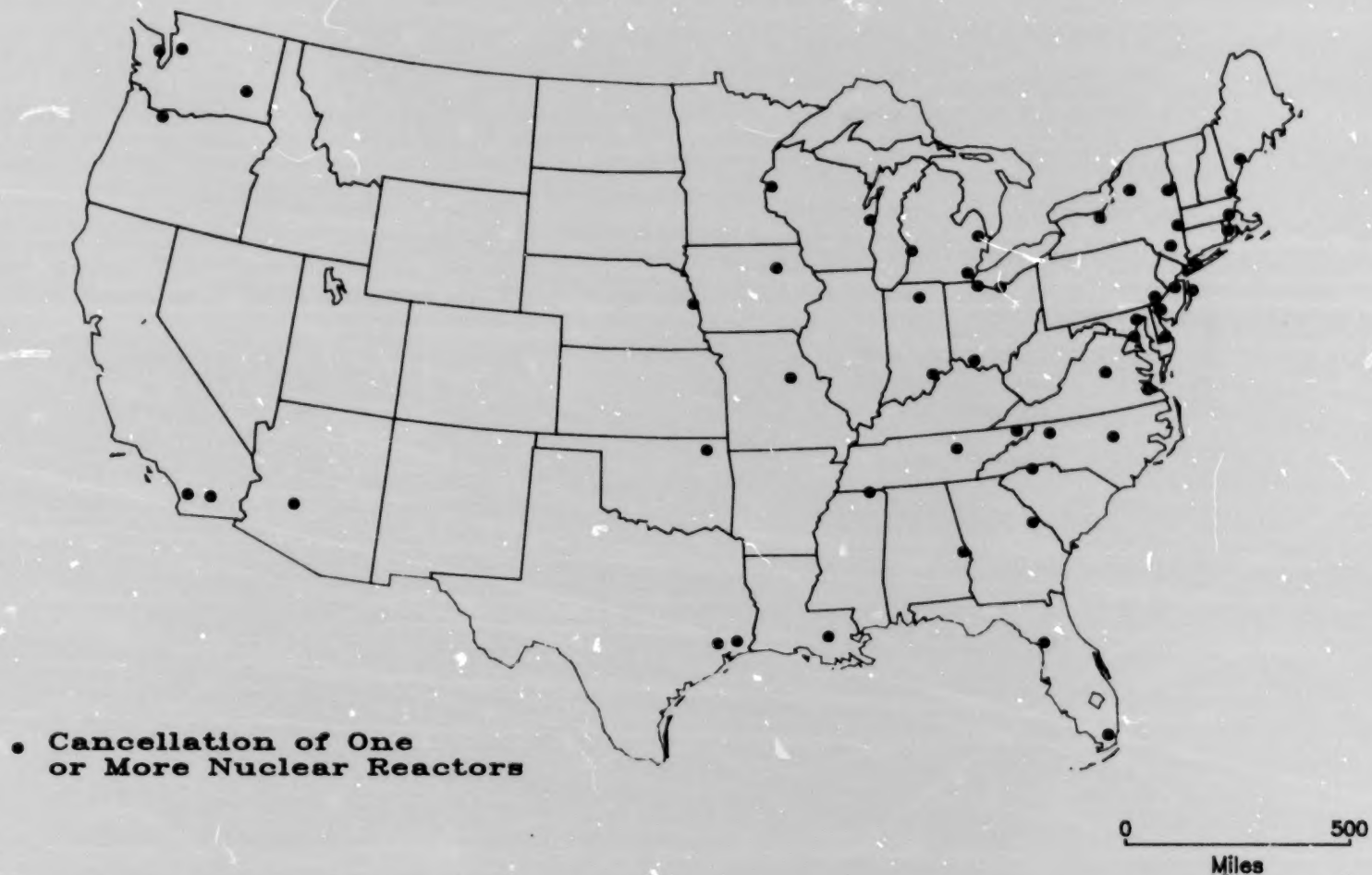
Source: *Nuclear News*, February, 1984.

Predictions were made in the late 1960s that by the end of the 20th century the United States would have several hundred power reactors producing more than 50% of the electricity for the nation. In the mid-1980s it is more realistic to project a few more than one hundred reactors by the year 2000, supplying approximately 15% of the nation's electricity. The challenge facing most of the power companies in 1984 is to complete those reactors which are under construction. It appears unlikely that any new nuclear power construction will be initiated in the remaining years of this century. In mid-1984 it would appear that a status report of the Nuclear Industry would be as follows: 78 operating nuclear reactors, three reactors licensed but not operating, 40 reactors under construction, and 16 reactors with construction permits on which work has either never begun or has been delayed or halted.

Is there an explanation for this loss of momentum in growth of commercial nuclear power? It is the answer to this question that often fuels the controversy between pro- and anti-nuclear groups. Both would agree, we think, given the economic conditions of 1984 (interest rates, inflation, construction time, etc.), the standards applied by the Nuclear Regulatory Commission, and the projections for future electrical energy consumption, the construction of commercial power reactors is not a good investment. Reactors which only ten years earlier had cost two to three hundred million dollars are costing from two to three billion up to as much as six to eight billion dollars in 1984. Many public utilities are under severe financial strain to finance the escalating construction cost of their nuclear plants. Examples of this are cited in the next section on cancellations. The dream we had for nuclear power in the 1960s is getting more and more faint in 1984.

¹ *Nuclear Industry*, January, 1984, page 3.

CANCELLATION OF POWER REACTORS, 1984



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CANCELLATION OF POWER REACTORS

There are few new technologies that have offered so much promise, attracted so much investment capital, and had such a brief period of growth and expansion as Commercial Nuclear Power. We noted earlier that the 1960s was a time of growth for the industry, which reached its peak from 1970-1974 when 140 orders were placed for commercial nuclear reactors. The orders then dropped off rapidly and ended completely in 1978. What persisted, however, was cancellations. Most of the reactors ordered during the 1970-74 period were eventually cancelled, and cancellations of these, and others have continued, and totaled more than 100 by mid-1984 (Table 8). Thus the number of planned or projected reactors for the United States has been steadily decreasing since the mid-1970s.

The term "cancellation" as used in the nuclear power industry may be misleading. In most instances it has meant cancelling the order, and thus abandoning plans to build a particular power reactor. In some instances the planned reactor had not been named, for some a site had not been selected, and for most, actual construction work on the reactor had not begun. The common reason for most cancellations was "reduced load growth." That is, the projected demand for electricity was growing slower than originally planned, thus there was less need for new generating plants. This kind of cancellation generally had little or no adverse financial impact on a utility company since relatively little had been invested. Since the late 1970s, however, cancellations have often been quite different.

Almost half of all cancellations of orders for power reactors happened in the early 1980s, due to a complex of circumstances. The fact that something in the industry was different became clear in 1984 when construction plans were abandoned (official cancellation will probably follow) for a number of projects into which hundreds of millions, and even billions of dollars had been invested. Some utility companies were delaying, slowing down, or stopping work on one nuclear project, hoping this would help them avoid cancellation of other projects. But, when the Washington Public Power Supply System defaulted on bonds in early 1984 shock waves went through the industry. Unit 1 and Unit 3, which were 60% and 70% completed, would probably never be finished. In that same year the Public Service Company of Indiana abandoned efforts to complete the twin-reactor Marble Hill Plant after spending two and one-half billion dollars (Unit 1 was 59% complete, Unit 2 was 37% complete). Also, the Cincinnati Gas and Electric Company abandoned construction of its Zimmer Plant (also in 1984) even though it was 97% complete

Table 8
ORDERS AND CANCELLATIONS OF
POWER REACTORS

Date	Orders Placed	Cancellations Announced
1965	7	0
1966	20	0
1967	31	0
1968	16	0
1969	7	0
1970	14	0
1971	21	0
1972	38	6
1973	41	0
1974	26	8
1975	4	11
1976	3	2
1977	4	9
1978	2	13
1979	0	8
1980	0	16
1981	0	6
1982	0	18
1983	0	6
1984	0	5*
Totals:	234	108

* Preliminary

Source: Atomic Industrial Forum, "Historical Profile of U.S. Nuclear Power Development, January 1, 1984." *Background Info.*

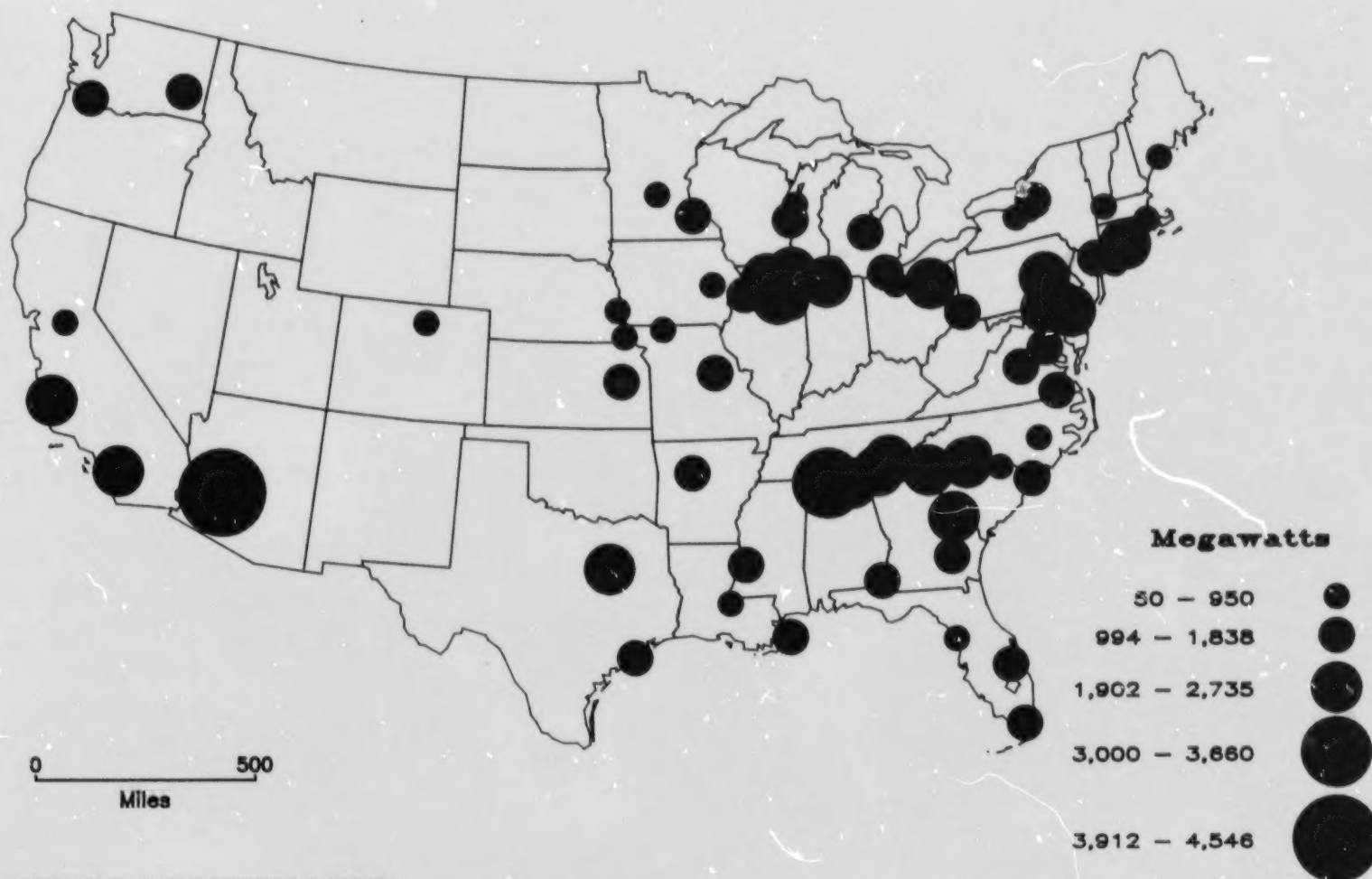
and had cost nearly two billion dollars. And, Public Services of New Hampshire stopped work on Seabrook #2 in September, 1983, and then halted work on Seabrook #1 in April 1984 (it was 39% complete) because of financial strain.¹ Most would agree, we believe, that utility companies that are building one or more nuclear reactors in 1984 are experiencing a financial strain to keep the projects moving forward.

¹As this went to press there was a news report that Public Services of New Hampshire had arranged financing to continue construction work on Unit #1 of the Seabrook Plant.

A new economic climate prevails in 1984 than that which had been dominant a decade and a half earlier. There is some public skepticism, there are serious economic constraints, yet the industry argues that this has been a good investment, and that the public is benefitting by having electricity costs that are lower than they would otherwise be. One cannot know at this time what the future will be for the nuclear industry, but it would appear that 1984 is a "wait and see" stage.

The distribution of cancellations shows a greater dispersion than some previous maps. Approximately two-thirds of the map symbols represent specific sites that had been selected for construction of power reactors (or where construction had actually begun). The remaining symbols, however, are located within the service area of the public utility that had planned construction, but for which a site was not selected. The fifty-four power plants represent more than 100 reactors that have been cancelled, but on fewer than thirty had there been major construction work done at the time of cancellation. A final comment. More than a dozen of these plants are the same as ones shown on previous maps—either under construction or operating. The explanation is that some utilities had, for example, planned a plant with four reactors, cancelled two of them, but completed the other two. In this example, therefore, the plant is shown as operating, as well as a site where there had been a cancellation.

PROJECTED CAPACITY OF COMMERCIAL NUCLEAR POWER PLANTS, 1999



PROJECTED CAPACITY OF COMMERCIAL NUCLEAR POWER PLANTS, 1999

The location and distribution of nuclear power plants in the United States will change very little in the remaining years of this century. In making this statement we assume that most of the reactors operating in 1984 will continue to the end of the century, and that most of the reactors under construction in 1984 will be completed. We have, however, removed from inclusion those reactors which began operating prior to 1970 in the belief they will be either retired or decommissioned by 1999. With these assumptions made the United States should have 71 commercial nuclear power plants with 112 operating nuclear reactors in 1999 (Table 21, Appendix). This falls considerably short of the predictions made in the late 1960s but it does reflect the impact that realities have had on the industry.

The nuclear power map at century's end will be different, however, from the 1984 map, if only in a few details. For example, the nation's largest nuclear power plant will be in Arizona, and Texas, Louisiana, Missouri, and Kansas will be on the nuclear map. The three nuclear regions identified earlier will continue, but with some changes. The Southern Nuclear Region will be the nation's largest with twelve plants, twenty-three reactors producing 23% of the nation's electricity generated by nuclear energy. The Atlantic Seaboard will be divided into the Northern Megalopolis Nuclear Region of New England and Southern New York and the Southern Megalopolis Nuclear Region extending from Eastern Pennsylvania southward through New Jersey, Maryland and Virginia. Combined, these two parts of Megalopolis will have fifteen plants with twenty-four nuclear reactors producing 21% of the nation's electricity generated by nuclear energy. The smallest, though most compact in 1999 will be the Chicago Nuclear Region. Within 150 miles of Chicago there will be eight nuclear plants with fourteen reactors producing 13.4% of the nation's electricity generated by nuclear energy. In 1999 these three regions will have half of the nuclear power plants, more than half of the reactors, and be producing 57% of the nation's electricity generated by nuclear plants.

In addition to the changes noted above, there will be a greater "dispersion" of nuclear plants in 1999, and with this the emergence of some other, smaller nuclear regions. For example, there will be the Mideast Nuclear Region of Southeast Michigan and North Ohio, a Gulf Coast Nuclear Region extending from Southern Florida through South Georgia, South Alabama, Mississippi, Louisiana and including the two

nuclear plants in Texas and the Southwest Nuclear Region of Southern California and Arizona. There may be other clusters worthy of identification but we will leave that to the reader to see her or his nuclear regions of the future.

Table 9
THE SOUTHERN NUCLEAR REGION, 1999

Name	Reactors	Capacity (MWe)
Salem	2	2,305
Peach Bottom	2	2,130
Susquehanna	2	2,100
North Anna	2	1,814
Calvert Cliffs	2	1,685
Surry	2	1,576
New Hope	1	1,067
Limerick	1	1,065
Three Mile Island	1	819
Totals	15	14,561

Table 10
THE NORTHERN MEGALOPOLIS NUCLEAR REGION, 1999

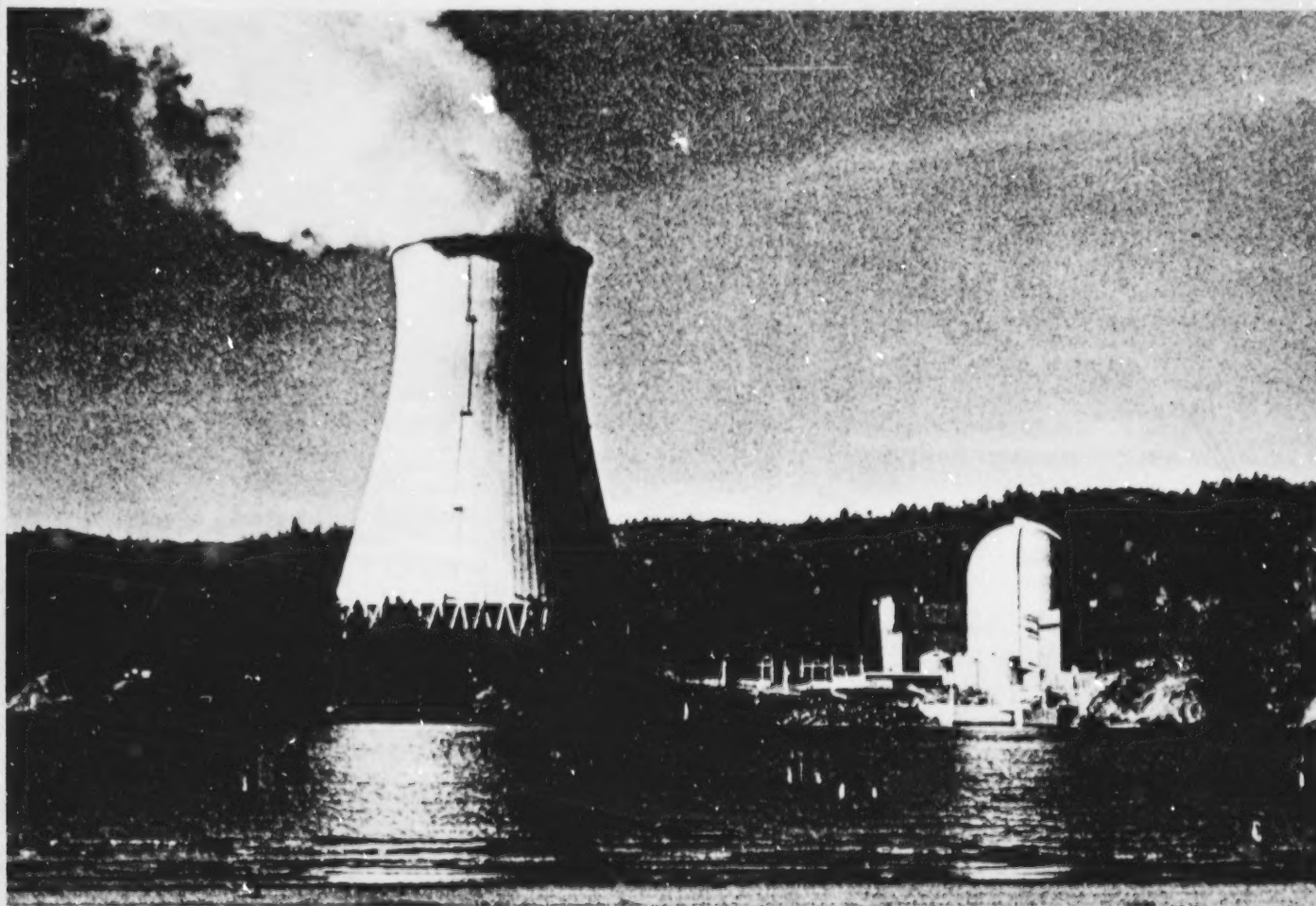
Name	Reactors	Capacity (MWe)
Millstone	3	2,689
Indian Point	2	1,838
Shoreham	1	849
Maine Yankee	1	825
Pilgrim	1	655
Vermont Yankee	1	514
Totals	9	7,370

Table 11
THE SOUTHERN MEGALOPOLIS NUCLEAR REGION, 1999

Name	Reactors	Capacity (MWe)
Browns Ferry	3	3,195
Oconee	3	2,661
Bellefonte	2	2,470
McGuire	2	2,360
Watts Bar	2	2,330
Sequoyah	2	2,296
Catawba	2	2,290
Vogtle	2	2,200
Brunswick	2	1,642
Shearon Harris	1	915
Summer	1	900
Robinsville	1	700
Totals	23	23,959

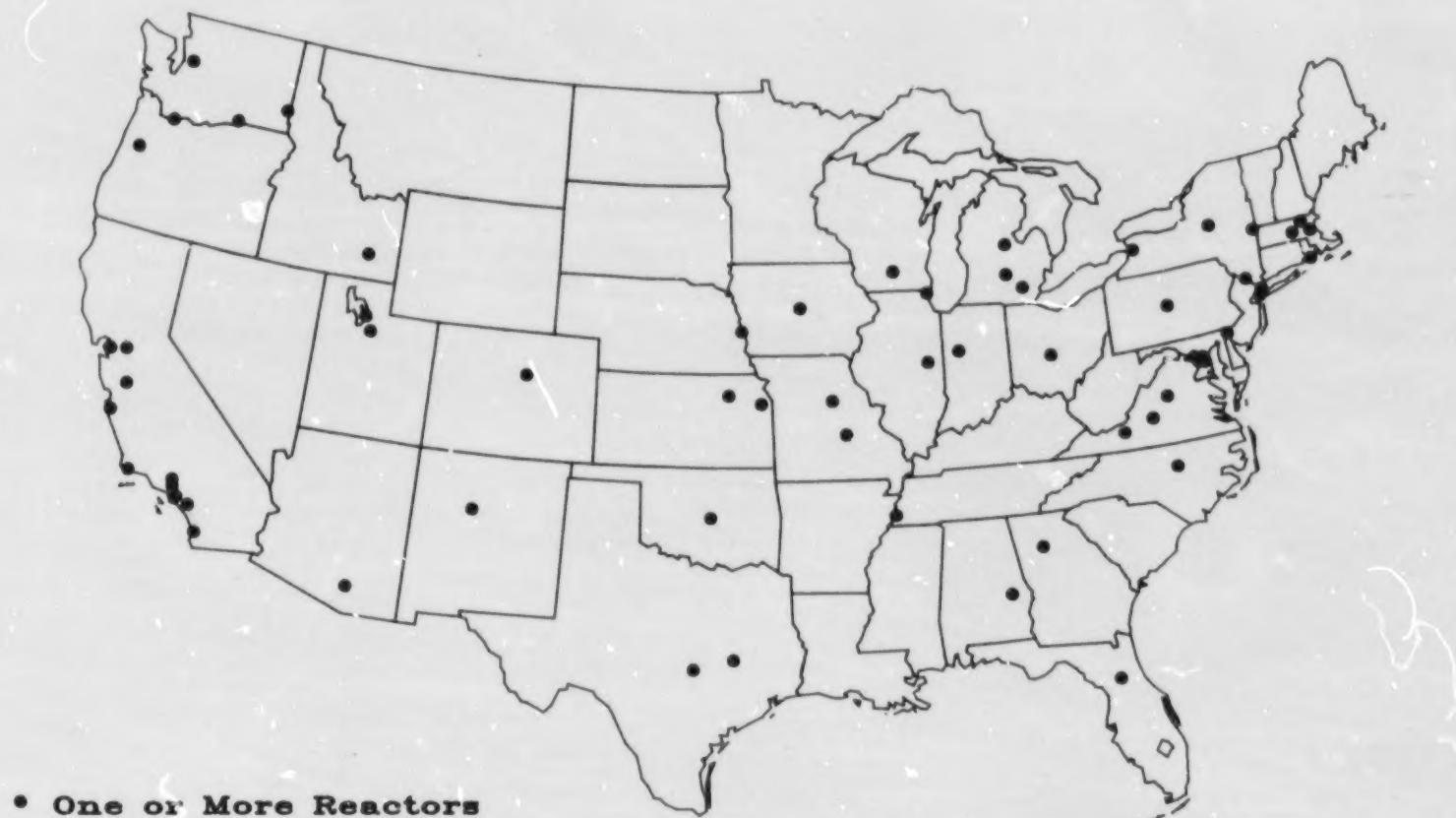
Table 12
THE CHICAGO NUCLEAR REGION, 1999

Name	Reactors	Capacity (MWe)
Byron	2	2,240
Braidwood	2	2,240
LaSalle	2	2,156
Cook	2	2,130
Zion	2	2,080
Dresden	2	1,588
Clinton	1	950
Palisades	1	805
Totals	14	14,089



This single reactor Trojan Nuclear Power Plant is located on the Columbia River 40 miles north of Portland, Oregon and has been operating since 1976. Photo by Jeff Becker provided through the courtesy of Ms. Diane C. Carruthers and the Atomic Industrial Forum, Inc.

NON-POWER NUCLEAR REACTORS, 1984



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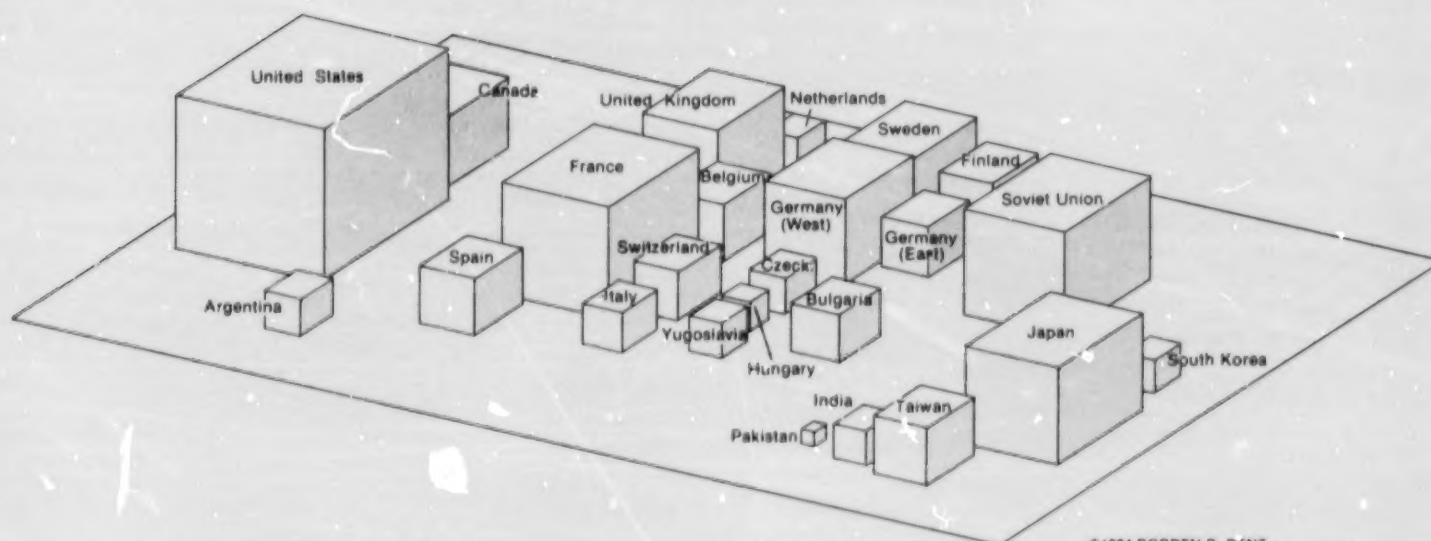
NON-POWER NUCLEAR REACTORS

It would be misleading to give the impression from our discussions and maps of nuclear power in the United States that public power utilities are the only participants involved in construction and operation of nuclear reactors. The U.S. Department of Defense operates more nuclear reactors, by far, than any other single entity (and probably more than all others combined). In addition, there are many nuclear reactors used for research. All previous maps in this Atlas thus far (as well as those that follow) have shown only commercial nuclear power plants, and we have noted, in a general way, the location and distribution of these plants. It is interesting to now note that a different distribution results by focusing on the seventy non-power reactors in the United States. The northern midsection of the country is void, as is Nevada, a number of Southern States, and most of New England. We see here a greater dispersion or a "different arrangement" than we have seen before. California emerges as the region with the greatest concentration, while there are smaller clusters of three or four reactors in various other locations.

Most of the reactors shown are relatively small, have a very low power output, and are used for basic research. Fifty-two of these reactors are at major universities of the nation which helps to explain their distribution. It is for this reason that we see the cluster in Massachusetts and this explains five of the reactors in California. In the Midwest, most of the "Big Ten" universities are represented, and similarly in each of the other regions, most of the major universities are shown. Knowing this, it therefore is not surprising that these nuclear reactors have a different distribution than the power reactors shown on all other maps of this Atlas.

There are eighteen non-power research and experimental reactors in the nation that are not maintained by universities. Five of these are used by agencies of the federal government (such as the U.S. Geological Survey, the Veterans Administration, and the National Bureau of Standards), while the others are operated by industries that participate in either design and engineering, construction, or supplying materials for power reactors, such as Babcock and Wilcox, General Electric, General Atomic Company, and Westinghouse.

WORLD NUCLEAR POWER, 1984



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Explanatory Legend

The cubes represent countries having commercial nuclear power production. Each cube is drawn so that its volume is proportional to megawatts of electricity produced. For example, the cube for Pakistan represents 125 megawatts, and that for the United States, 65,584 megawatts.

WORLD NUCLEAR POWER, 1984

In the early days of nuclear research and development (1950s and 1960s) there was much competition among the nuclear nations of the world for technological supremacy. The Soviet Union and the United States were the principal early contestants in this race, and each was promoting sale of its reactors to other nations. By the late 1960s the United States was rising into a dominant position, but several other nations also had successful research programs and prototype power reactors in operation. The United Kingdom and France had experimented in development of gas-cooled reactors. Canada had developed the more efficient heavy water reactors, but each of these nations was several years behind the United States which had opted for the light water reactor. This early technological lead of the United States and its aggressive marketing programs through outright sale and licensing agreements gave it the advantage, and in the 1970s most of the reactors built by Japan, France, and West Germany were based on designs developed in the United States.¹

It should be recalled that in the 1960s there was much optimism about the future of nuclear power, and this was shared, not only by the industrial nations of the world, but also by the undeveloped nations. Thus the diffusion of this new technology began early in its history—within the nation where it developed, but also to many Third World nations for which the promise of cheap electrical power was especially attractive. By 1984, when the industry was barely thirty years old, there were twenty-four nations with operating power reactors (Table 13), and another eight (Austria, Brazil, China, Mexico, Philippines, Poland, Rumania, and South Africa) that would probably join the group of nuclear nations by the end of the 1980s.

All maps in this ATLAS show nations and continents in forms and shapes that are familiar to most people. Our World Map of Nuclear Energy, however, is different. It is not a traditional map at all, but is a cartogram, in which nations are represented by cubes whose volumes represent the nuclear power production of each country. Note that only the nuclear nations are shown, and these are in their approximate relative geographical locations to other nuclear nations. We have selected this method to show world production because of the immediate visual impact. It is quite clear that the United States leads in world production, and that France, the Soviet Union, Japan, West Germany, United Kingdom, Canada, and Sweden stand out from the other nations. Together, the United States and Canada stand isolated from the rest of the world, at least in terms of world nuclear energy production.

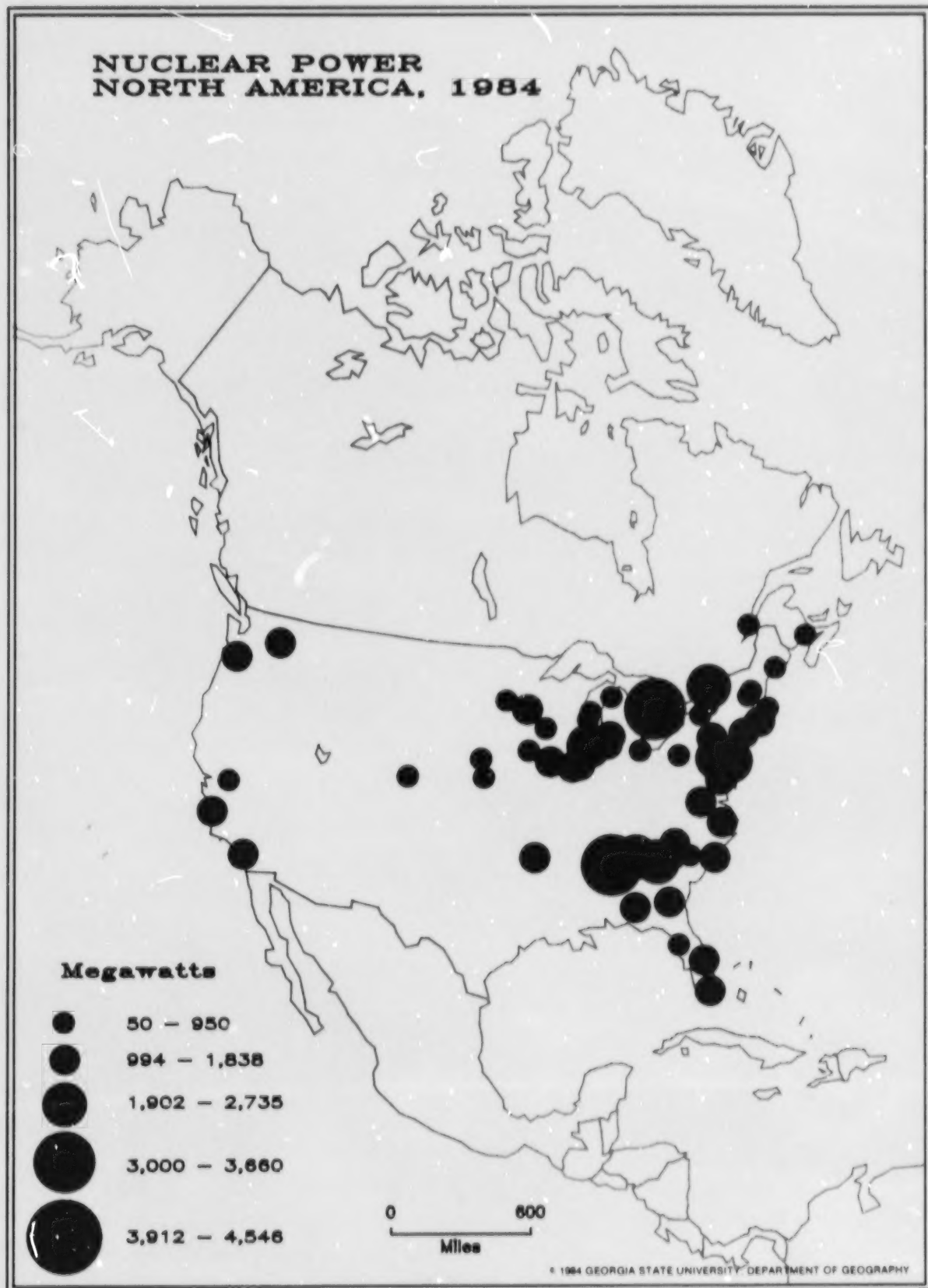
Table 13
WORLD NUCLEAR POWER PRODUCTION 1984

Name	Operating Reactors	Capacity (MWe)
United States	81*	65,584
France	36	26,228
U.S.S.R.	34	18,355
Japan	25	16,600
West Germany	12	9,806
United Kingdom	33	8,648
Canada	10	7,410
Sweden	10	7,325
Belgium	5	3,450
Taiwan	4	3,110
Spain	5	2,890
Finland	4	2,210
Switzerland	4	1,940
East Germany	5	1,830
South Korea	3	1,790
Bulgaria	4	1,760
Czechoslovakia	3	1,320
Italy	3	1,285
Argentina	2	935
India	4	804
Yugoslavia	1	615
Netherlands	2	495
Hungary	1	440
Pakistan	1	125
World Total	285	184,955

*Three reactors which have not operated for several years have been included.

Source: "World List of Nuclear Power Plants," *Nuclear News*, February, 1984, pp. 71-90.

¹Christopher Flavin, *Nuclear Power: The Market Test*, Paper No. 57. Washington, D.C.: Worldwatch Institute, 1983, p. 11.



NUCLEAR POWER, NORTH AMERICA, 1984

There are ten nations on the North American continent, but only the United States and Canada are generating electricity with nuclear power in 1984. Mexico has two 654 megawatt reactors under construction at a plant on its East Coast near Veracruz, and will be the third "Nuclear Nation" of North America, but operation of that plant is not expected until the late 1980s. Since the first part of this Atlas was devoted exclusively to the United States, it seems appropriate here to make a few observations about nuclear energy in Canada.

First, it is interesting to note that the Canadian nuclear plants are either close to, or on the United States—Canadian border, thus it does not appear that Canada has a "separate" nuclear region. The nuclear plants of one nation merge with those of the adjoining nation. One critical element in the locational decisions of nuclear power plants is energy demand (usually related to population density and/or industrial development). The overwhelming majority of Canada's population and industry is in the St. Lawrence Valley and the Ontario Peninsula, and most of its nuclear plants are located to serve those two regions. Unlike other nations of the developed world, Canada has grouped most of its nuclear capacity on two individual sites, both of which serve those two regions. At Tiverton, Ontario (on Lake Huron) the Bruce Plant has four operating reactors and four more under construction while the Pickering Plant (also in Ontario but located on Lake Ontario) has five operating reactors and three under construction. Each of these plants

will have eight operating reactors by the end of the decade. No other nation, except Japan, has planned for such concentrations of nuclear reactors on a single site. In addition, Canada has three smaller nuclear plants (the symbol for one is lost under the symbol for the Bruce Plant). In sum, Canada has thirteen operating power reactors and eight more under construction (Table 14).

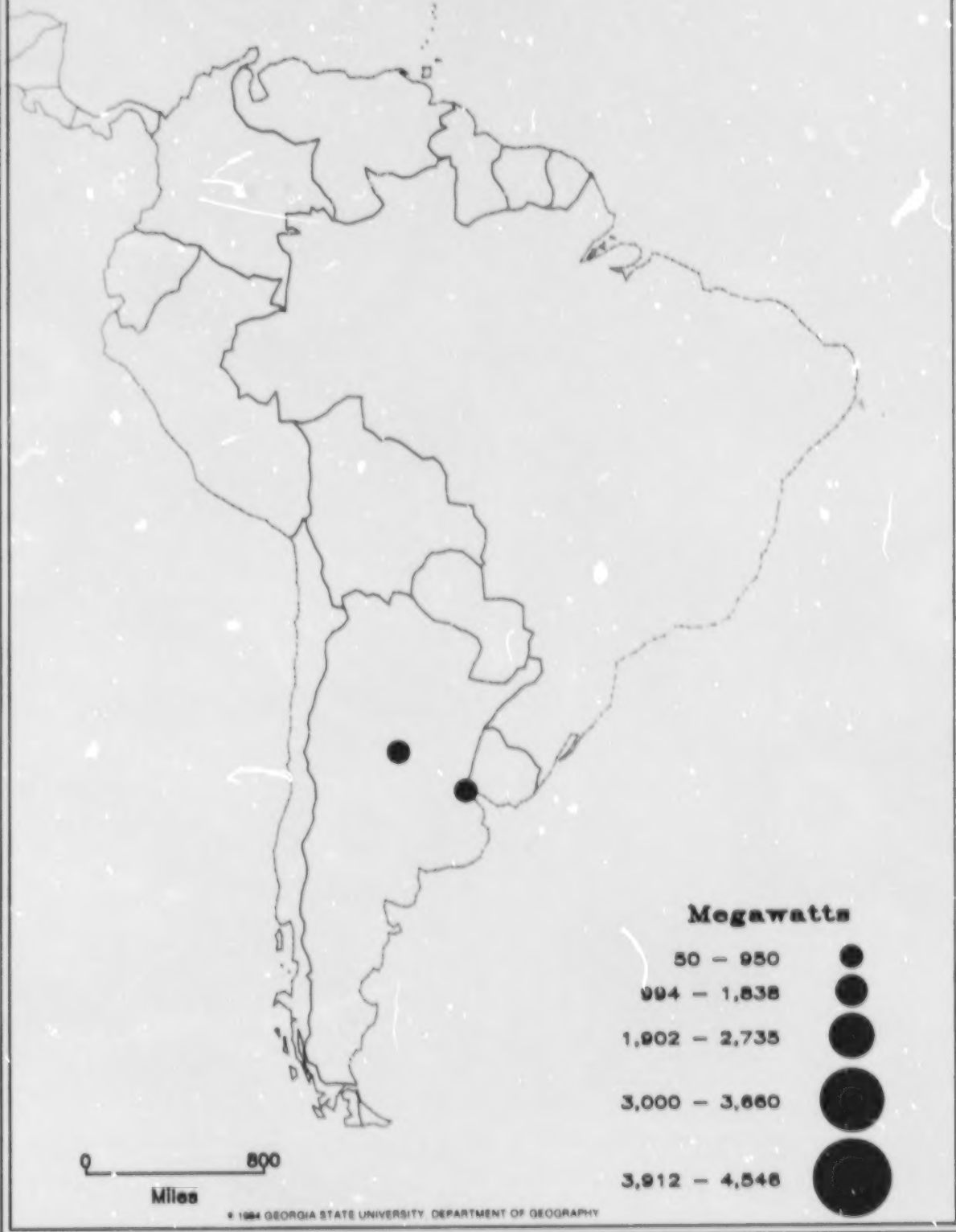
It is again noted that each of the Canadian nuclear power plants is located on water—Lake Huron, Lake Ontario, the St. Lawrence River, or the Bay of Fundy. Water, essential for reactor cooling is obviously another important element in siting decisions of nuclear power plants.

Table 14
NUCLEAR POWER PLANTS IN CANADA, 1984

Name	Operating Reactors	No. under Construction	Capacity Megawatts
Bruce	4	4	3,200
Pickering	5	3	2,576
Gentilly	2	0	888
Point Lepreau	1	0	640
Douglas Point	1	0	206
Newcastle Twp.	0	1	—
Totals	13	8	7,410

Source: "World List of Nuclear Power Plants," *Nuclear News*, February, 1984, pp. 72-73

NUCLEAR POWER SOUTH AMERICA, 1984



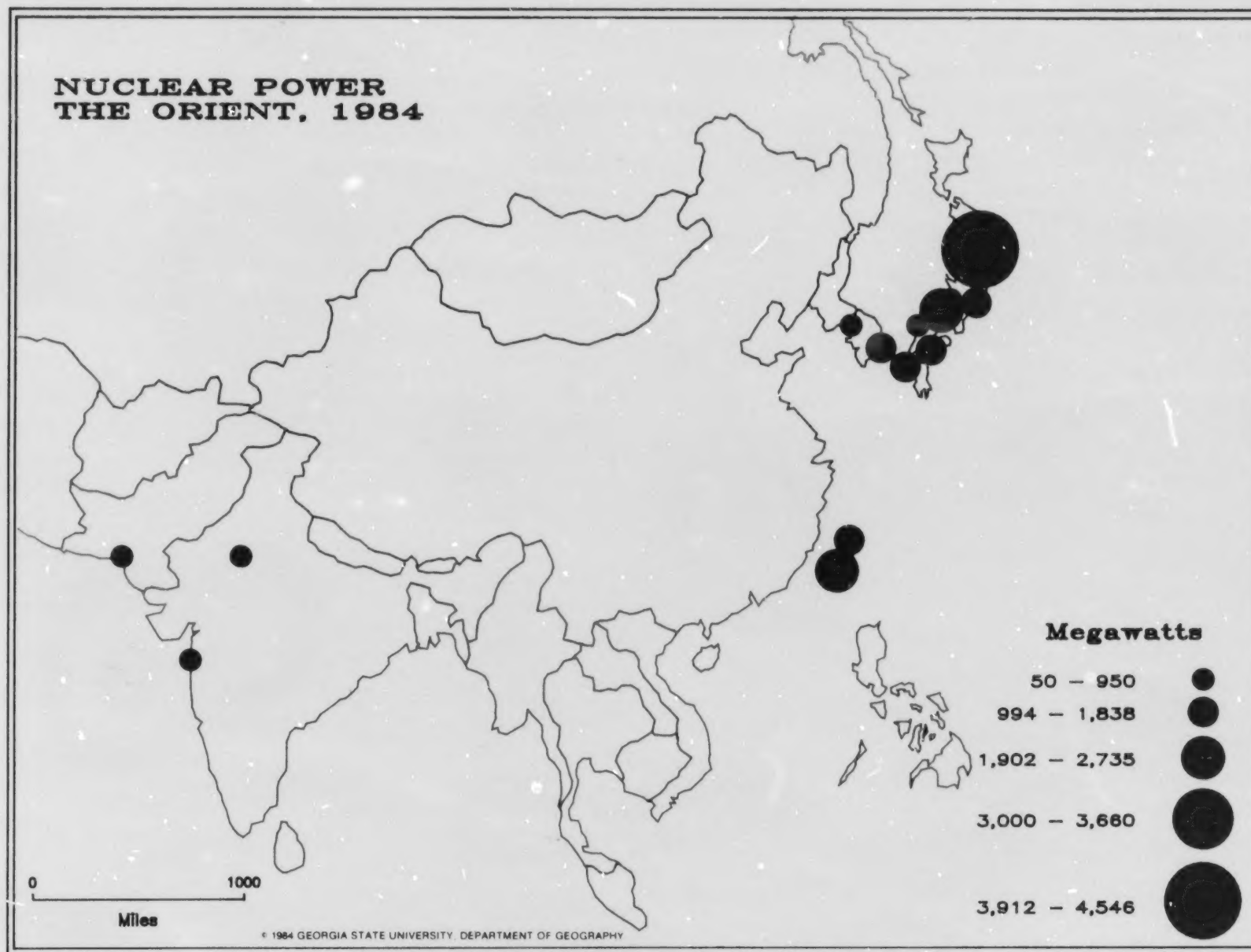
NUCLEAR POWER, SOUTH AMERICA, 1984

Argentina, unlike many other non-industrial nations of the world, had an early interest and commitment in nuclear research. In the late 1950s its first research reactor was operating, and in the 1960s two more were completed. It was also in the late 1960s that Argentina contracted with a West German Company to build its first nuclear power plant. This was the 335 megawatt Atucha #1 reactor located at Lima (50 miles northwest of Buenos Aires) that began commercial operations in 1974. In the late 1970s a contract was awarded to a different West German firm to build Atucha #2 on the same site. This was for a 692 megawatt reactor, originally scheduled to be operating in 1987, but numerous delays will postpone that until at least 1990. In addition, Argentina has the single reactor, 600 megawatt Embalse Plant located at Rio Tercero (50 miles south of Córdoba or 400 miles northwest of Buenos Aires) which was designed by a Canadian firm, built by Italian companies, and began commercial operation in 1983. Argentina also has plans for more nuclear reactors, but a worsening economic situation in the 1980s renders these plans and timetables in doubt at mid-decade.¹

The other nation with a nuclear power program in South America is Brazil. Like Argentina, Brazil has had research reactors and plans for nuclear power development, but they did not order their first power reactor until 1972 (from Westinghouse of the United States). This was Angra #1, a 600 megawatt reactor located at Itaorna (60 miles southwest of Rio de Janeiro). This plant was originally scheduled to begin operation in 1977, but a series of problems (literally dozens of serious fires suggesting the possibility of arson and sabotage) have delayed completion, but commercial operation is expected sometime in 1984. Two additional reactors are to be built on the same site by arrangements with companies from West Germany. The first of these (Angra #2) is to be a 1245 megawatt reactor which is under construction but on which there have been numerous delays, and operation cannot reasonably be expected before 1990. And, Angra #3, identical to Angra #2, is planned for the same site.

Brazil, like many nations of the Third World during the 1960s and 1970s, had plans for major growth in construction and operation of nuclear power plants. The adverse economic conditions of Third World Nations in the 1980s, however, have dealt a severe blow to most of those plans, causing them to be delayed indefinitely. It would appear in 1984 that Argentina and Brazil are the only nations of South America we can reasonably expect to have commercially operating nuclear power plants during the remainder of this century.

¹This, and the section on the Orient which follows, are drawn from James Everett Katz and Onkar S. Marwah, *Nuclear Power in Developing Countries: An Analysis of Decision making*. Lexington, Massachusetts: D.C. Heath and Company, 1982.



NUCLEAR POWER, THE ORIENT, 1984

There are only five nations of the orient which use nuclear energy to generate electricity, namely Japan, Taiwan, South Korea, India, and Pakistan. China and the Philippines each have nuclear plants under construction which are scheduled to begin operating later this decade. And, contrary to trends discussed elsewhere in this Atlas, China has plans to greatly expand its construction of nuclear power plants. Japan, one of the world's leading nuclear nations, is not discussed here, but is covered in a separate treatment which follows.¹

Pakistan has one small reactor (125 megawatts) which was built by General Electric of Canada, and has operated since 1972. It is located near Karachi and provides half of the electricity used by that coastal city. India has four small reactors. The two near Bombay (200 megawatts each), were built by General Electric of the United States and have been generating electricity since 1969. The other two are located near Kota in Rajasthan (midway between Delhi and Bombay), and have operated since the early 1970s. One of these was provided by General Electric of Canada while the other was built by a local firm under an agreement with Canada. Both are 202 megawatts. In addition, India has four reactors under construction; two in the southern state of Tamil Nadu and another two in the northern state of Uttar Pradesh, all of which are scheduled to begin operating before 1990, and each of these has a rating of 220 megawatts. It is interesting to note that all of the nuclear plants in South Asia, either operating or under construction, have only the small "First Generation Reactors."

Two other nations of the Orient have recently joined the "Nuclear Club" with a serious commitment—South Korea and Taiwan. South Korea has two operating reactors near Pusan City (provided by Canada), each of which generates from 550 to 630 megawatts of electricity. South Korea has six additional reactors under construction which are scheduled to begin operation in the late 1980s, all of which are rated at 900 megawatts or more. This will give South Korea more than 7,200 megawatts of electrical generating capacity from nuclear power by 1990 and make it one of the major nuclear nations of the world.

Taiwan has the second largest nuclear power capacity in the Orient (after Japan). There are two reactors in the north rated at 604 megawatts each, and two more in the south, each rated at 951 megawatts. In addition, two other reactors of 907 megawatts are under construction and scheduled to be operating by the end of 1985, which will give Taiwan a total capacity from nuclear energy of almost 5,000 megawatts. This is projected to supply approximately 40% of all electrical needs on the island.²

Table 15
NUCLEAR POWER PLANTS IN THE ORIENT, 1984

Country	Operating Reactors	No. under Construction	Capacity (MWe)
Japan	25	11	16,600
Taiwan	4	2	3,110
South Korea	3	6	1,790
India	4	4	804
Pakistan	1	0	125
Philippines	0	1	— —
China	0	1	— —
Totals	37	25	22,429

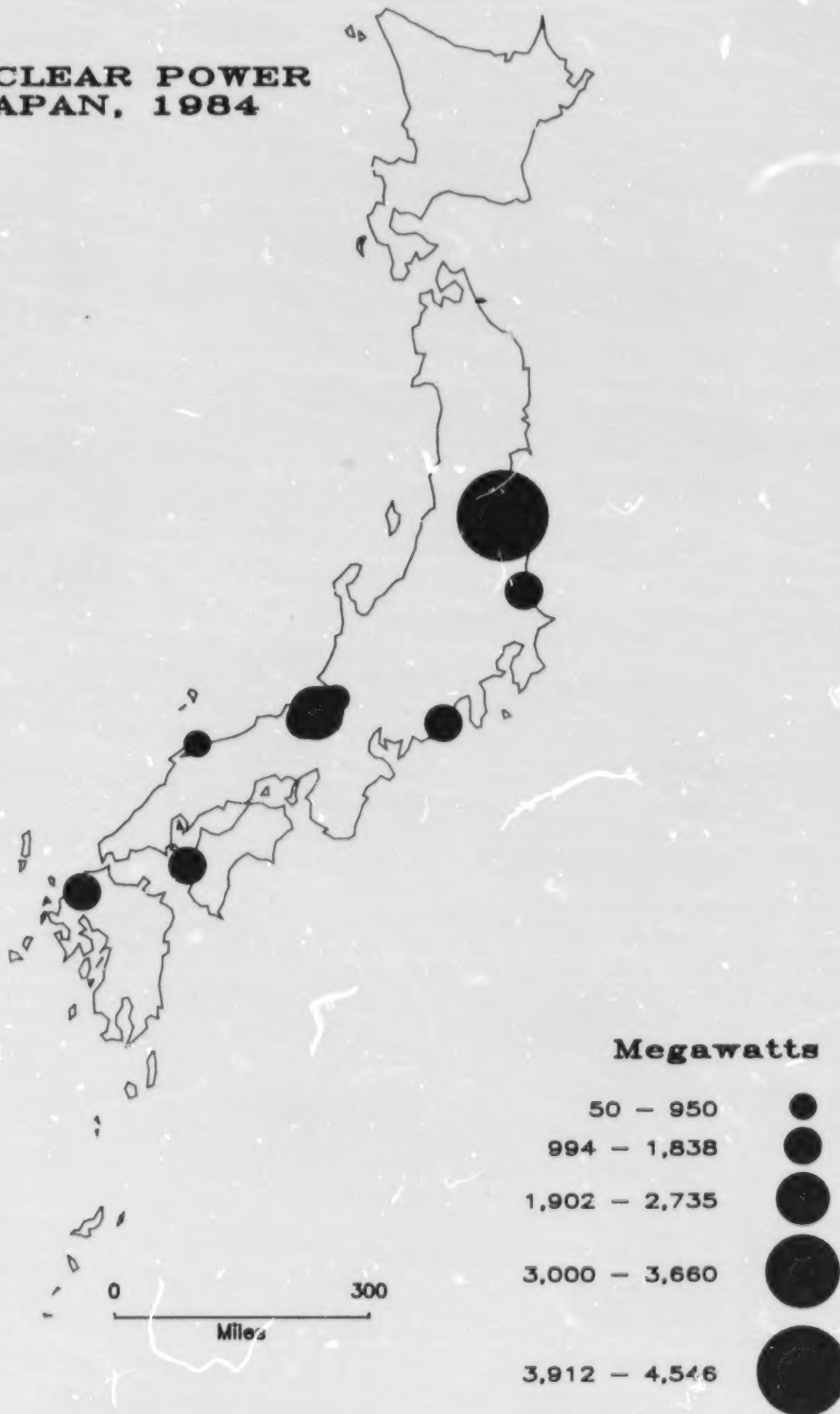
Source: "World List of Nuclear Power Plants," *Nuclear News*, February, 1984, pp. 73-84

The disparity between rich nations and poor nations is evident on the Orient map. This continent is a huge land area and home for more than half of the world's people, yet only in Japan (one of the rich nations) is there a clustering of nuclear power plants. It is now common, however, to call South Korea and Taiwan, not poor nations but Newly Industrializing Countries (NICs), and we note they are developing significant nuclear power capacity. So the only really poor nations of the region with operating nuclear power reactors are Pakistan and India. Poor nations lack nuclear power plants, not simply because they lack technological development, since there are vendors in France, Japan, the United States, Canada, West Germany, the United Kingdom and the Soviet Union who are ready and willing to export the technology. The reality which this map shows so well is that this technology is tremendously expensive. Few nations of the world have the money to invest in nuclear power plants.

¹This section is drawn largely from Katz and Marwah, *op. cit.*

²*Ibid.*, p. 305.

NUCLEAR POWER JAPAN, 1984



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NUCLEAR POWER, JAPAN, 1984

Nuclear power production in the Orient is dominated by Japan which produces 16,600 megawatts of electricity from twenty-five reactors operating on eleven sites. Furthermore, fifteen reactors are under construction and another two are planned. If all of these achieve operating status Japan's total capacity from nuclear energy will be in excess of 30,000 megawatts.

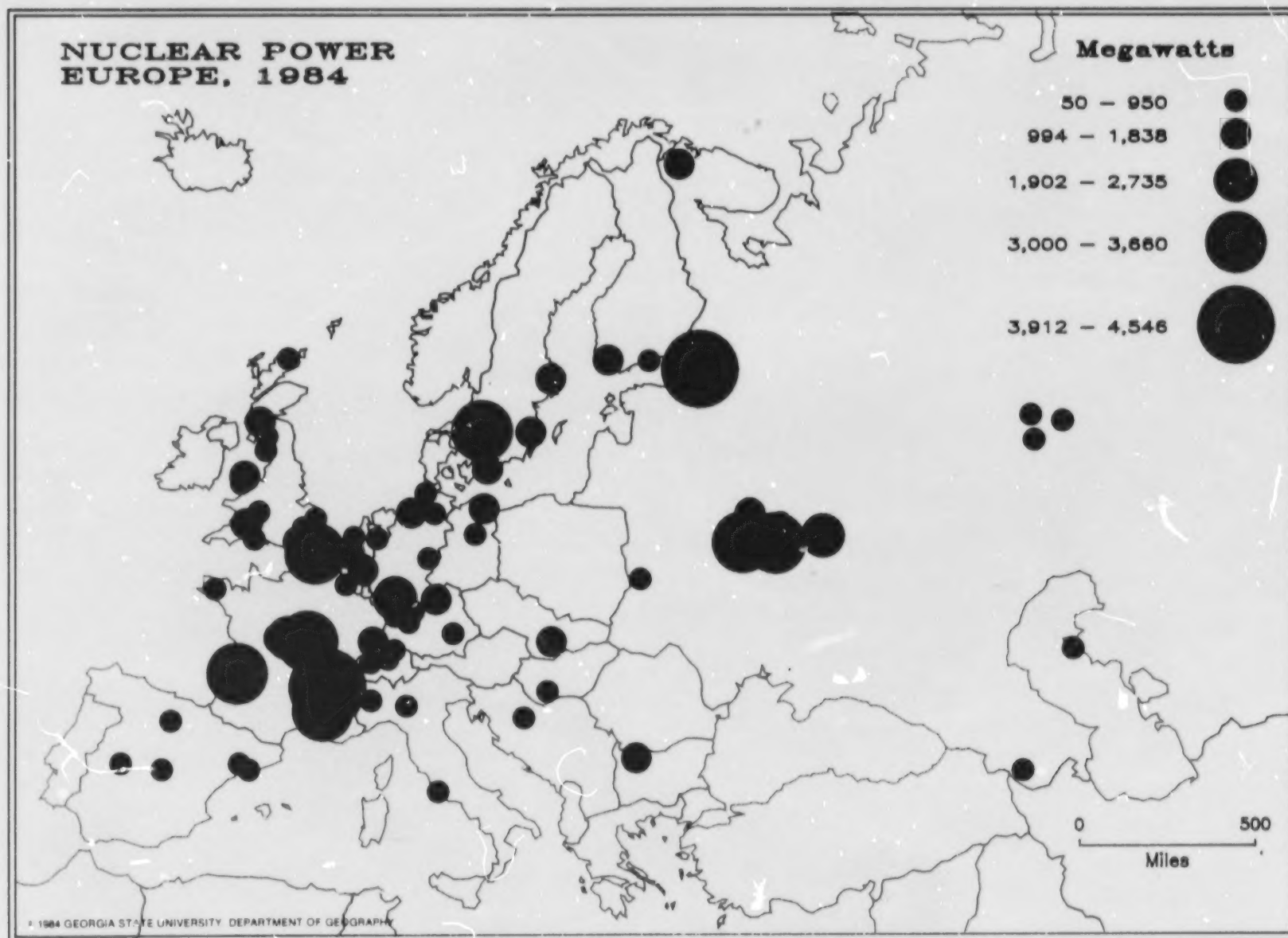
Nuclear energy has, understandably, been controversial in Japan, but the country was still one of the early adoptors of this new technology. Tokai #1, a small 159 megawatt "First Generation Reactor" located north of Tokyo, has been operating since 1966. That first plant, however, was not of local origin. The reactor, the generator and the engineering were all supplied by General Electric of the United Kingdom. Four of Japan's other reactors were supplied by General Electric and another four were supplied by Westinghouse, both of the United States. Beginning in the 1970s, however, the Japanese industrial giants have been dominant. Mitsubishi was licensed by Westinghouse, and Toshiba and Itachi were each licensed by General Electric of the United States, to provide the design and engineering, and to supply the reactors and generators for nuclear plants. Other domestic companies have been doing the actual construction work. One of these firms is also supplying the generators for the nuclear power plants under construction in Mexico, so Japan is now competing with other developed nations for export markets of this technology.

The population and major industrial districts of Japan are concentrated in a relatively small area, extending from east to west along southern Honshu (the large island), and including the northern fringe of the two other main islands of Shikoku and Kyushu. Their nuclear power plants, however, are outside this area, but close enough to serve industry and the dense populations. The area fronting Wakasa Wan, on the Sea of Japan coast, which has nine operating reactors (and three more under construction) is only 150 miles from the great industrial and population centers of Nagoya and Osaka-Kobe. Beyond that we note the sites are dispersed, but close enough to serve major population centers, such as Fukushima (Japan's largest nuclear plant with seven operating reactors), located 150 miles north of Tokyo. Hokkaido, the northernmost island, has no operating reactors in 1984, but two are under construction and scheduled to be generating electricity by the end of the decade. When all reactors under construction are completed, Japan will have nuclear power plants distributed throughout its land providing more than half of their total national electrical power needs.

Table 16
NUCLEAR POWER PLANTS IN JAPAN, 1984

Location	Operating Reactors	No. under Construction	Capacity (MWe)
Fukushima (Daiichi)	6	0	4,546
Ohi	2	0	2,240
Mihama	3	0	1,570
Takahama	2	2	1,560
Hamaoka	2	1	1,330
Tokai Mura	2	0	1,226
Ikata	2	0	1,076
Fukushima (Daini)	1	3	1,067
Genkai	2	0	1,058
Tsuruga	2	1	488
Shimane	1	0	439
Niigata	0	3	— —
Sendai	0	2	— —
Tomari	0	2	— —
Oshikagan	0	1	— —
Totals for Japan	25	15	16,600

Source: "World List of Nuclear Power Plants," *Nuclear News*, February, 1984, pp. 76-77



NUCLEAR POWER, EUROPE, 1984

The history of nuclear power on the continent of Europe has been somewhat parallel to the United States' experience. The 1950s were devoted to research with France, West Germany, United Kingdom, and the Soviet Union making particularly strong commitments of money and resources. Each of these countries had small power reactors operating in the late 1950s and early 1960s, and soon after plans were formulated for growth and expansion of the industry. In the 1970s, however, most nations were reassessing the role of nuclear power, and thus were modifying the grandiose plans of the previous decade. The nuclear power programs of the major nations of Europe each had some distinctive characteristics which are discussed briefly here.¹

The Soviet Union, an early pioneer in nuclear power, devoted some of its early efforts at developing a "standardized" reactor for use at home, and for sale to other nations, but efforts at "streamlining" the construction process did not produce the desired results. They are committed to growth of nuclear power but are significantly behind in attaining the goals set in the early 1970s. The United Kingdom had an early thrust of enthusiasm for nuclear power in the 1950s, but costs and retention of a limiting technology (the gas cooled reactors) makes it appear its plans for nuclear energy are being drastically reduced. Eight of its reactors are less than 100 megawatts, each of which dates from the 1950s, and another fourteen date from the early 1960s and none is more than 300 megawatts. In fact, the United Kingdom does not have, either operating or under construction, a single reactor with a capacity as much as 700 megawatts. And West Germany, which did not start as early, nevertheless, made a major commitment to nuclear power in the 1960s and initiated plans and construction projects for large, third generation plants in the 1970s. Political opposition (led by the environmentally conscious Green Party) and deteriorating economic conditions, however, forced a reassessment and cancellation of many of these plans.

Only in France, the fourth of these European nations, has the nuclear program continued to grow, contrary to trends in the United States and other nations of Europe. France leads all of Europe, not only in production of electrical energy from nuclear reactors, but in the number of operating reactors, and in its future plans for nuclear power. No nation has shifted so rapidly away from fossil fuels and to nuclear power as France, and one concern now is they may soon have a surplus of electrical generating capacity. One other European nation that has made a relatively large nuclear commitment is Sweden. It has twelve operating reactors, and two more that should be completed in 1985.

Table 17
NUCLEAR POWER PLANTS IN EUROPE, 1984

Nation	Operating Reactors	No. under Construction	Capacity (MWe)
France	36	23*	26,228
USSR	34	24*	18,355
West Germany	12	9*	9,806
United Kingdom	33	9	8,648
Sweden	10	2	7,325
Belgium	5	2	3,450
Spain	5	5*	2,890
Finland	4	0	2,210
Switzerland	4	1*	1,940
East Germany	5	0*	1,830
Bulgaria	4	0	1,760
Czechoslovakia	3	8	1,320
Italy	3	3	1,285
Yugoslavia	1	0	615
Netherlands	2	0	495
Hungary	1	3	440
Rumania	0	3*	—
Austria	0	1	—
Poland	0	0*	—
European Total	162	93	88,597

*Additional reactors are planned

Source: "World List of Nuclear Power Plants," *Nuclear News*, February, 1984, pp. 71-90

which is a major nuclear program for a nation with only a little more than eight million people. But as this program grew, so did public opposition to it, and a national referendum conducted in 1980 directed that there be no new construction starts. So each of these nations of Europe has a nuclear program, and each would appear to be at a "crossroads" in that program, but their characteristics tend to be distinctive, and thus generalizations for the entire continent are difficult. Some comment should be made, however, about the distribution of nuclear power capacity in Europe.

The Continent of Europe (including the Western or European portion of the Soviet Union) has approximately the same area as the United

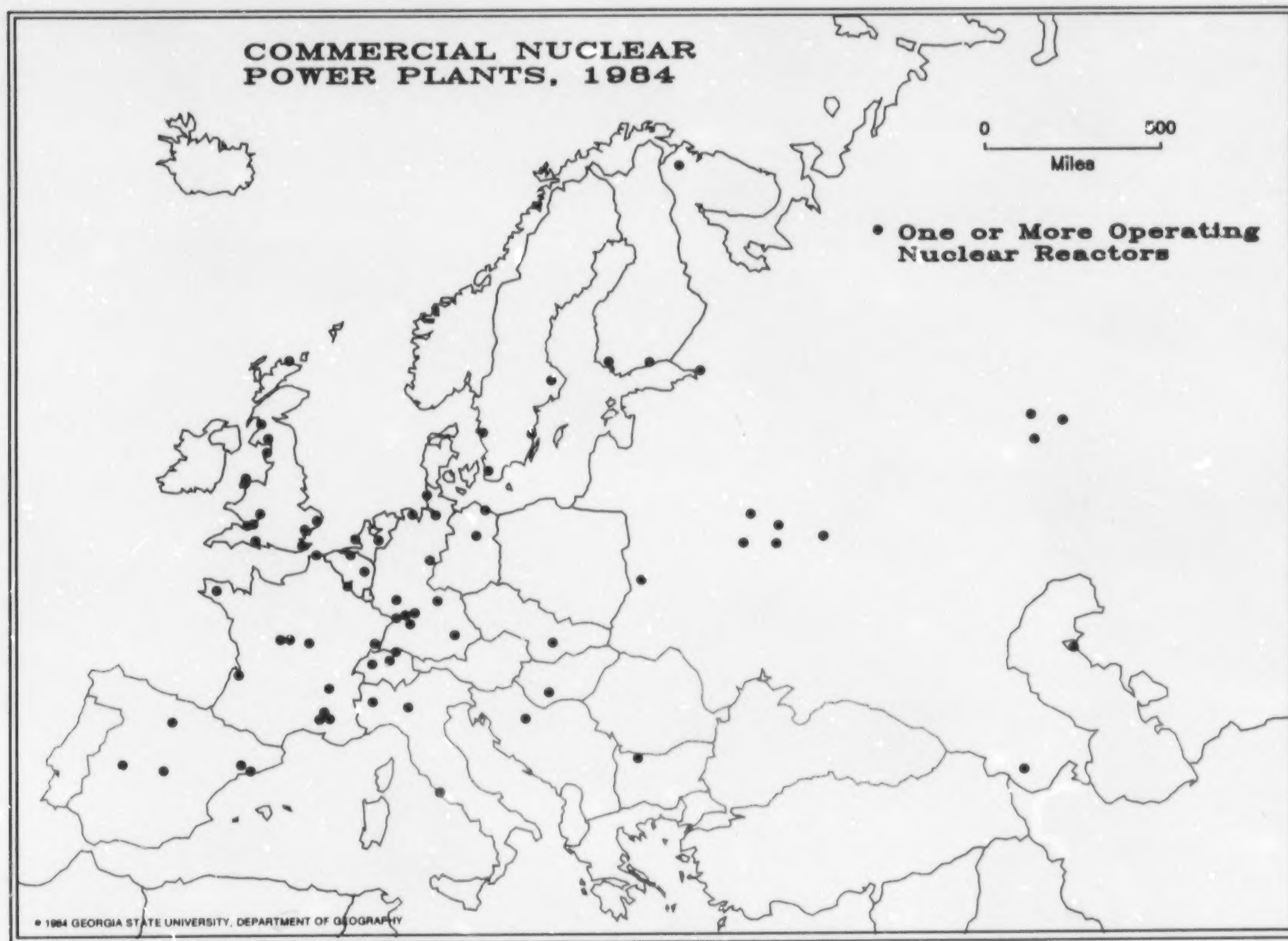
¹These summaries are drawn largely from Goldschmidt, *op. cit.*

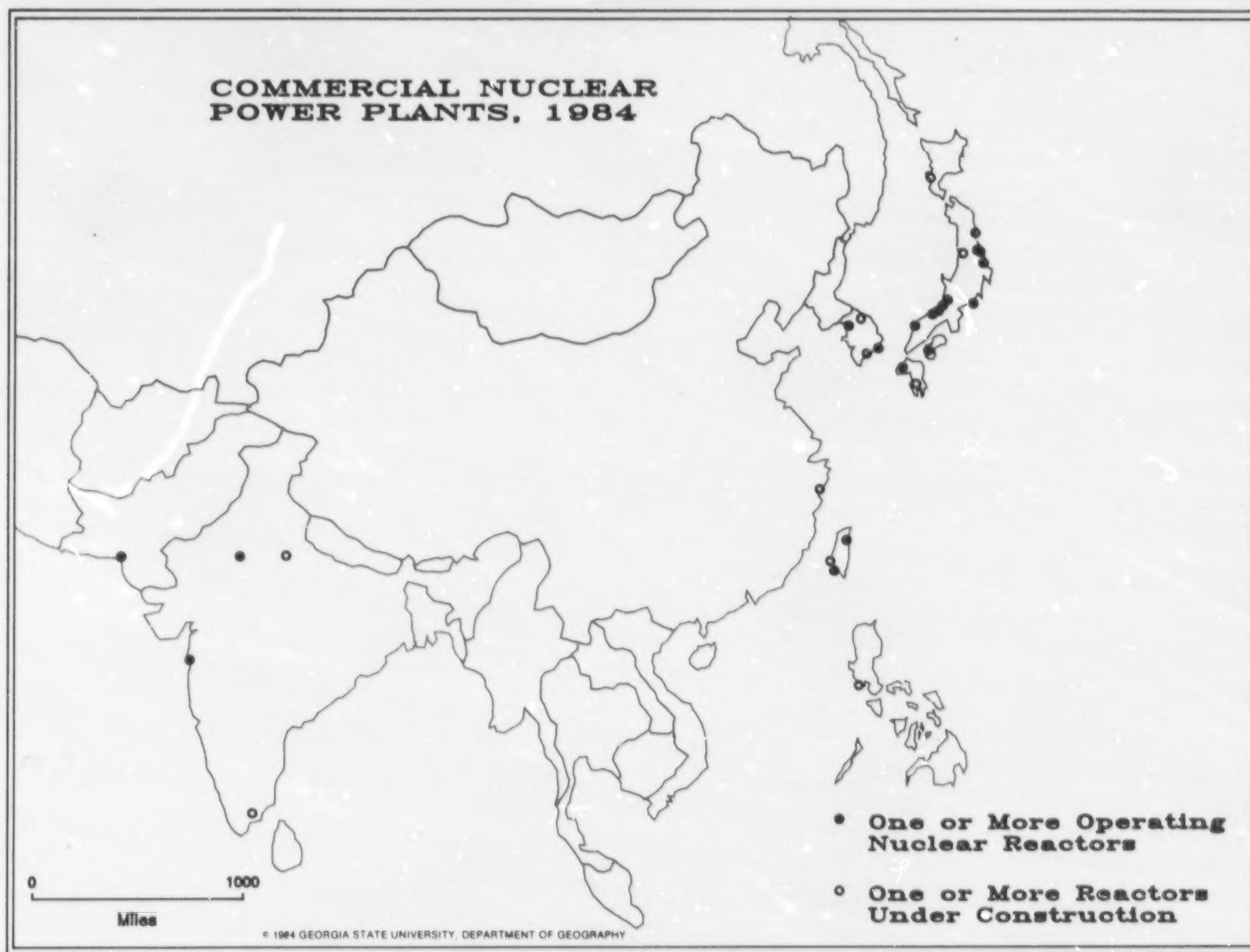
States, yet it is composed of more than twenty-five nations and has three times the population. Since this is the greatest concentration of people and nations in the developed world it should not be surprising that the nations of Europe have more than twice as many operating nuclear reactors as the United States although their total power capacity exceeds that of the United States by only twenty-five per cent.

Most European nuclear power is clustered in five regions, all but one of which extends across international boundaries. The most obvious concentration is the Franco-Alpine Nuclear Region which includes the five large nuclear plants in Southern France and the nearby, but smaller plants in northern Italy and Switzerland. Another major concentration is the Industrial Middle Europe Nuclear Region extending from the large plant in northern France at Dunkerque (and the three small plants of southeastern Great Britain) through Belgium and including all of West Germany. A third, more linear region is the Baltic Sea Nuclear Region extending from the giant plant at Leningrad, through Finland, Sweden, and including the two plants in northern East Germany. The most compact of the clusters is the Moscow-Northern Ukraine Nuclear Region of the Soviet Union. This includes three large plants and two smaller ones (one small circle is hidden by a larger one) and serves the area of the nation with greatest population density. And finally, there is the Western Britain Nuclear Region extending from northern Scotland southward along western Great Britain, and including the small French plant on the Peninsula of Brittany (Bretagne). This region is on a par with some others in the number of reactors, but it is much less significant in total power capacity.

In addition to these five nuclear regions there are seventeen small nuclear plants in Europe, most with only one reactor, and most spatially detached or isolated from the nuclear regions. Seven of these "outliers" are in the Soviet Union and extend in a circular pattern from Murmansk in the far north to the three small plants on the eastern slopes of the Ural Mountains, to the shores of the Caspian Sea, the southern Caucasus Mountains, and to the border area with Poland. Four more plants (three of Soviet design) are in Eastern Europe, and all of the remainder are in Spain except for the one in peninsular Italy.

It is unlikely that the general pattern shown here will change in the next decade or two. More reactors will be added to existing power plants, some of the small, older reactors will be retired or decommissioned, and some new plants will come into being, but this basic pattern will undoubtedly persist to the end of the century, and perhaps beyond.





APPENDIX

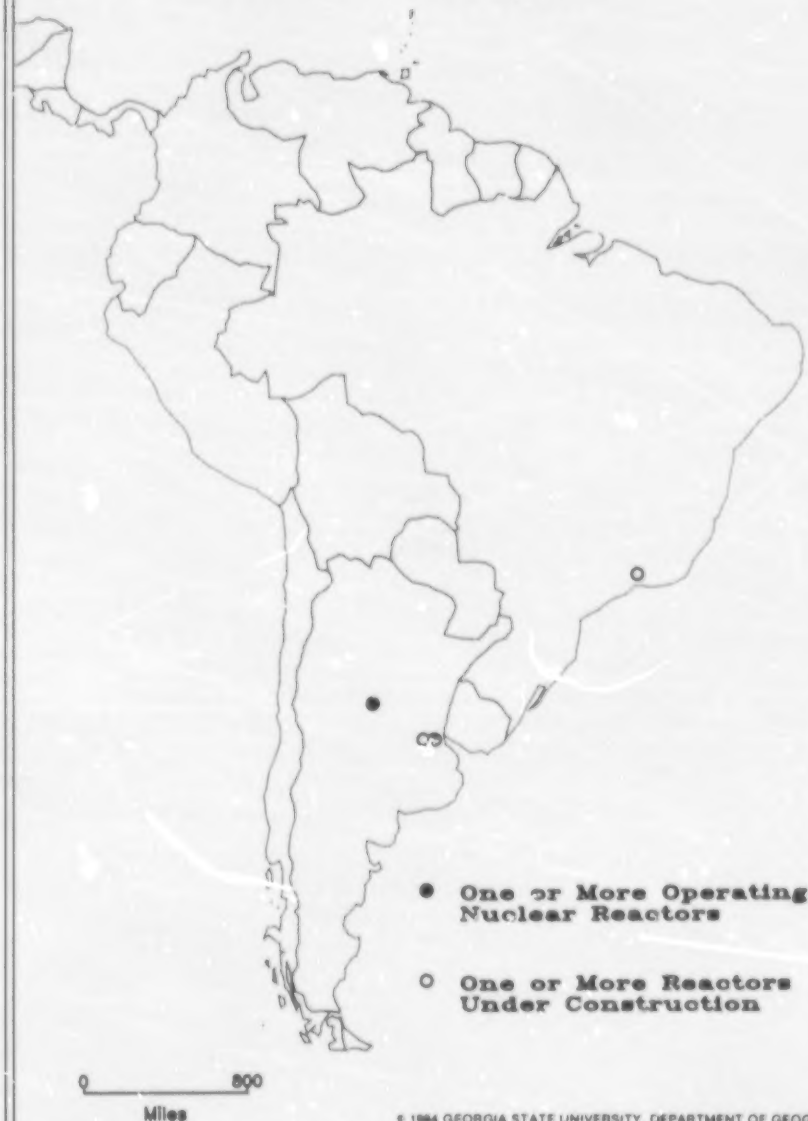
**COMMERCIAL NUCLEAR
POWER PLANTS, JAPAN
1984**



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APPENDIX

**COMMERCIAL NUCLEAR
POWER PLANTS, 1984**



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COMMERCIAL NUCLEAR POWER PLANTS, 1984



Table 18
NUCLEAR POWER PLANTS IN THE UNITED STATES, 1984

Plant	Reactors	Location	Capacity (MWe)
Browns Ferry	3	Limestone Co., Alabama	3,195
Oconee	3	Oconee Co., South Carolina	2,661
San Onofre (a)	3	San Diego Co., California	2,636
Salem (b)	2	Salem Co., New Jersey	2,305
Sequoyah	2	Hamilton Co., Tennessee	2,296
Cook	2	Berrien Co., Michigan	2,130
Peach Bottom	2	York Co., Pennsylvania	2,130
Zion	2	Lake Co., Illinois	2,080
Indian Point	2	Westchester Co., New York	1,838
North Anna	2	Louise Co., Virginia	1,814
Arkansas	2	Pope Co., Arkansas	1,762
Calvert Cliffs	2	Calvert Co., Maryland	1,685
Farley	2	Houston Co., Alabama	1,658
Brunswick	2	Brunswick Co., N. Carolina	1,642
St. Lucie	2	St. Lucie Co., Florida	1,634
Dresden (c)	2	Grundy Co., Illinois	1,588
Quad Cities	2	Rock Island Co., Illinois	1,578
Surry	2	Surry Co., Virginia	1,576
Hatch	2	Appling Co., Georgia	1,561
Millstone	2	New London Co., Connecticut	1,530
Turkey Point	2	Dade Co., Florida	1,386
McGuire	1	Mecklenburg Co., N. Carolina	1,180
Trojan	1	Colombia Co., Oregon	1,130
Wash. Nuclear (d)	1	Richland, Washington	1,103
Diablo Canyon (e)	1	San Luis Obispo Co., Calif.	1,084
LaSalle (f)	1	LaSalle Co., Illinois	1,078
Susquehanna	1	Columbia Co., Pennsylvania	1,065
Prairie Island	2	Goodhue Co., Minnesota	1,060
Point Beach	2	Manitowoc Co., Wisconsin	994
Rancho Seco	1	Sacramento Co., California	918
Davis-Besse	1	Ottawa Co., Ohio	906
Summer	1	Fairfield Co., South Carolina	900
Hanford Nuclear	1	Richland, Washington	860
Beaver Valley	1	Beaver Co., Pennsylvania	834
Crystal River	1	Citrus Co., Florida	825
Maine Yankee	1	Lincoln Co., Maine	825
Fitzpatrick	1	Oswego Co., New York	821
Three Mile Island (g)	1	Dauphin Co., Pennsylvania	819
Palisades	1	Van Buren Co., Michigan	805
Cooper Station	1	Nemaha Co., Nebraska	778
Robinson	1	Darlington Co., S. Carolina	700
Pilgrim	1	Plymouth Co., Massachusetts	655
Oyster Creek	1	Ocean Co., New Jersey	650
Nine Mile Point	1	Oswego Co., New York	620
Haddam Neck	1	Middlesex Co., Connecticut	582
Monticello	1	Wright Co., Minnesota	545
Duane Arnold	1	Linn Co., Iowa	538
Kewaunee	1	Kewaunee Co., Wisconsin	535
Vermont Yankee	1	Windham Co., Vermont	514
Fort Calhoun	1	Washington Co., Nebraska	478
Ginna	1	Wayne Co., New York	470
Fort St. Vrain	1	Weld Co., Colorado	330
Yankee Rowe	1	Franklin Co., Massachusetts	175
Big Rock Point	1	Charlevoix Co., Michigan	72
La Crosse	1	Vernon Co., Wisconsin	50

(a) Start-up tests on Unit #3 began in early 1984. Unit #1 was down for repairs.

(b) Unit #2 shut down for repairs.

(c) Unit #1 shut down indefinitely.

(d) Received license for fuel loading in January, 1984.

(e) Began low-level tests in early 1984.

(f) Start-up tests began in December, 1983.

(g) Unit #2 shut down indefinitely. Unit #1 has not operated since 1979.

Source: United States Nuclear Regulatory Commission, *Licensed Operating Reactors, Status Summary Report*, Vol. 6, No. 4 (April, 1984).

TABLE 19
THIRD GENERATION REACTORS
(Partial Listing)

Name	Location	Construction Began	Operation Began	Capacity (MWe)
Dresden #2	IL	1965	1970	809
Indian Point #2	NY	1965	1974	873
Dresden #3	IL	1966	1971	809
Quad Cities #1	IL	1966	1973	809
Quad Cities #2	IL	1966	1973	809
Oconee #1	SC	1966	1973	841
Oconee #2	SC	1966	1974	886
Three Mile Island #1	PA	1966	1972	810
Diablo Canyon #1	CA	1966	1984	1,060
Peach Bottom #2	PA	1966	1974	1,065
Peach Bottom #3	PA	1966	1974	1,065
Salem #1	NJ	1966	1977	1,050
Browns Ferry #1	AL	1966	1974	1,064
Browns Ferry #2	AL	1966	1974	1,064
Arkansas #1	AR	1967	1974	820
Calvert Cliffs #1	MD	1967	1975	800
Calvert Cliffs #2	MD	1967	1977	800
Zion #1	IL	1967	1973	1,050
Zion #2	IL	1967	1974	1,050
Indian Point #3	NY	1967	1976	965
Oconee #3	SC	1967	1974	886
Beaver Valley #1	PA	1967	1976	847
Cook #1	MI	1967	1975	1,054
Cook #2	MI	1967	1978	1,060
Limerick #1	PA	1967	**	1,065
Limerick #2	PA	1967	**	1,065
Salem #2	NJ	1967	1981	1,050
Browns Ferry #3	AL	1967	1977	1,065

**Still not operating in mid-1984

Source: U.S. Atomic Energy Commission, *The Nuclear Industry*, 1970. Washington, D.C.: Government Printing Office, 1970, pp. 154-155, and *Nuclear News*, various dates.

Table 20
NUCLEAR POWER PLANTS UNDER CONSTRUCTION

Plant	Reactors	Location	Capacity (MWe)
Palo Verde	3	Arizona	3,810
South Texas	2	Texas	2,500
Bellefonte	2	Alabama	2,426
Perry	2	Ohio	2,410
Watts Bar	2	Tennessee	2,354
Comanche Peak	2	Texas	2,300
Catawba	2	South Carolina	2,290
Byron	2	Illinois	2,240
Braidwood	2	Illinois	2,240
Vogtle	2	Georgia	2,200
McGuire	1	North Carolina	1,180
Grand Gulf	1	Mississippi	1,150
Millstone	1	Connecticut	1,150
Wolf Creek	1	Kansas	1,150
Callaway	1	Missouri	1,150
Diablo Canyon	1	California	1,106
Waterford	1	Louisiana	1,104
Fermi	1	Michigan	1,100
Nine Mile Point	1	New York	1,080
LaSalle	1	Illinois	1,078
Hope Creek	1	New Jersey	1,070
Limerick	1	Pennsylvania	1,055
Susquehanna	1	Pennsylvania	1,050
River Bend	1	Louisiana	940
Clinton	1	Illinois	933
Shearon Harris	1	North Carolina	900
Beaver Valley	1	Pennsylvania	833
Shoreham	1	New York	820
Midland	1	Michigan	808
Totals	40		44,427

Source: "World List of Nuclear Power Plants," *Nuclear News*, February, 1984, pp. 85-89.

Table 21
NUCLEAR POWER PLANTS IN THE UNITED STATES, 1979

Power Plant	Location	Operating Reactors 1984	Operating Reactors 1999*	Capacity (MWe) 1999
Palo Verde	Arizona	0	3	3,912
Browns Ferry	Alabama	3	3	3,195
Millstone	Connecticut	2	3	2,689
Oconee	South Carolina	3	3	2,661
Bellefonte	Alabama	0	2	2,470
Perry	Ohio	0	2	2,410
McGuire	North Carolina	1	2	2,360
Watts Bar	Tennessee	0	2	2,330
Salem	New Jersey	2	2	2,305
Commanche Peak	Texas	0	2	2,300
Sequoyah	Tennessee	2	2	2,296
Catawba	South Carolina	0	2	2,290
Byron Station	Illinois	0	2	2,240
Braidwood	Illinois	0	2	2,240
San Onofre	California	3	2	2,200
Vogtle	Georgia	0	2	2,200
Diablo Canyon	California	1	2	2,190
LaSalle	Illinois	1	2	2,156
Peach Bottom	Pennsylvania	2	2	2,130
Cook	Michigan	2	2	2,130
Susquehanna	Pennsylvania	1	2	2,100
Zion	Illinois	2	2	2,080
Indian Point	New York	1	2	1,838
North Anna	Virginia	2	2	1,814
Arkansas	Arkansas	2	2	1,762
Calvert Cliffs	Maryland	2	2	1,685
Beaver Valley	Pennsylvania	1	2	1,666
Farley	Alabama	2	2	1,658
Brunswick	North Carolina	2	2	1,642
St. Lucie	Florida	2	2	1,634
Dresden	Illinois	2	2	1,588
Quad Cities	Illinois	2	2	1,578
Surry	Virginia	2	2	1,576
Hatch	Georgia	2	2	1,561
Turkey Point	Florida	2	2	1,386
South Texas	Texas	0	1	1,250
Grand Gulf	Mississippi	0	1	1,250

Callaway	Missouri	0	1	1,150
Wolf Creek	Kansas	0	1	1,150
Waterford	Louisiana	0	1	1,150
Trojan	Oregon	1	1	1,130
Washington Nuclear	Washington	1	1	1,103
Enrico Fermi	Michigan	0	1	1,093
Nine Mile Point	New York	1	1	1,080
Hope Creek	New Jersey	0	1	1,067
Limerick	Pennsylvania	0	1	1,065
Prairie Island	Minnesota	2	2	1,060
Point Beach	Wisconsin	2	2	994
Clinton	Illinois	0	1	950
River Bend	Louisiana	0	1	934
Rancho Seco	California	1	1	918
Harris	North Carolina	0	1	915
Davis-Besse	Ohio	1	1	906
Summer	South Carolina	1	1	900
Shoreham	New York	0	1	849
Crystal River	Florida	1	1	825
Maine Yankee	Maine	1	1	825
Fitzpatrick	New York	1	1	821
Midland	Michigan	0	1	808
Three Mile Island	Pennsylvania	0	1	819
Palisades	Michigan	1	1	805
Cooper Station	Nebraska	1	1	778
Robinson	South Carolina	1	1	700
Pilgrim	Massachusetts	1	1	655
Monticello	Minnesota	1	1	545
Duane Arnold	Iowa	1	1	538
Kewaunee	Wisconsin	1	1	535
Vermont Yankee	Vermont	1	1	514
Fort Calhoun	Nebraska	1	1	478
Ginna	New York	1	1	470
Fort St. Vrain	Colorado	1	1	330
Hanford Nuclear	Washington	1	0	--
Oyster Creek	New Jersey	1	0	--
Haddam Neck	Connecticut	1	0	--
Yankee-Rowe	Massachusetts	1	0	--
Big Rock Point	Michigan	1	0	--
LaCrosse	Wisconsin	1	0	--

* It is assumed that reactors which began operation prior to 1970 will be retired or decommissioned by 1999, thus they are not included here. Otherwise this table is a combination of Tables 18 and 20.

SOURCES

Many people believe that information about commercial nuclear power plants is classified and thus very secret. While this may have been true once it is not true today. Individual power companies that have operating nuclear plants, or companies that design and sell reactors, may have certain trade secrets, but we have found no shortage of information about nuclear power plants. The nuclear industry produces and distributes a great volume of material, most of the nuclear nations have one or more agencies that publish materials, and there are many books, journals and journal articles on the subject. We have scanned and read what seems like "mountains" of material in the past year, but for the sake of simplicity we are citing here only those sources which bear most directly on this Atlas.

The American Nuclear Society publishes *Nuclear News* which has been particularly helpful. This monthly magazine has news about nuclear plants in the U.S. and abroad, and once a year (usually in February) has a world listing of all power reactors of 30 or more megawatts that are operating, under construction, or on order. This list identifies the name, location, and power company that operates each reactor and gives a few details about them (their rating, type, supplier, date when operation began, and if under construction, its stage of completion and when operation is expected). The list which appeared in February, 1984 is the principal source of data for all maps and tables of this Atlas.¹ There are, however, three other listings that we used, either to verify data or for additional information. These include publications of the United States Nuclear Regulatory Commission (NRC), especially the monthly Status Summary Reports *Licensed Operating Reactors*, sometimes referred to as the "Graybook" (because of the color of its cover). This volume provides two or three pages of monthly technical, operating, and NRC inspection information on each operating commercial reactor in the United States. In addition it lists non-power reactors and reactors which have been permanently or indefinitely shut down. We also used *Nuclear Industry*, a monthly journal published by the Atomic Industrial Forum which reports news and from time to time has listings of U.S. and world reactors. Finally, we consulted *Nuclear Engineering International* (published in London), which has a world listing of nuclear plants in the August, 1983 supplement.

For an historical perspective we found that some of the reports of the old U.S. Atomic Energy Commission were both interesting and helpful. These give the sense of hope and optimism in the early days, and how far-reaching experimentation went in an effort to find new uses for nuclear power. Particularly useful were the reports prepared for delivery

to the annual conferences of the Atomic Industrial Forum, and which appeared annually as *The Nuclear Industry*, 1966 through *The Nuclear Industry*, 1970.

There were several volumes we found particularly relevant and helpful. A very succinct and non-technical history of nuclear power, written originally in French by one of the early pioneers is Bernard Goldschmidt, *The Atomic Complex: A Worldwide Political History of Nuclear Energy* (LaGrange Park, Illinois: American Nuclear Society, 1982). The first half of this volume is devoted to early history and the development of nuclear technology for military purposes. The second half, however, contains a brief history of each of the nations involved in developing nuclear power. Another valuable book is James Everett Katz and Onkar S. Marwah, *Nuclear Power in Developing Countries: An Analysis of Decision Making* (Lexington, Massachusetts: D.C. Heath, 1982). This volume has individual chapters on fifteen different developing countries that either have or are planning to have nuclear power plants for the generation of electricity. A comparison of these two volumes makes it clear that the developing countries confront quite different problems in adopting nuclear technology than do the industrialized nations. And finally there are two other general volumes that would be of interest and value to the newcomer on this topic. Christopher Flavin, *Nuclear Power: The Market Test* (Washington, D.C.: The Worldwatch Institute, 1983), is a brief pessimistic treatment of nuclear power that focuses primarily on the economic problems of the industry in the 1980s. The other, more substantial volume is *Nuclear Power in an Age of Uncertainty* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-E-216, February, 1984). This is perhaps the "definitive" assessment of the issues, problems, and opportunities of the nuclear power industry in the 1980s.

In closing we should identify two fruitful sources of information about the nuclear power industry. The Atomic Industrial Forum (7101 Wisconsin Avenue, Bethesda, MD 20814) provided maps, reprints, photographs, and copies of its own publications such as *Background Info*. And the Atlanta Office of the Nuclear Regulatory Commission gave us statistical data, copies of the "Graybook" and talked to us on the phone when we had questions. Many other references could be given here, but the above identifies the principal sources that were used in preparation of this Atlas.

¹During the first half of 1984 we relied on news reports in daily newspapers for some of our most recent information.

DEPARTMENT OF GEOGRAPHY RESEARCH SERIES PUBLICATIONS

Borden D. Dent, *Trade Area Analysis of Atlanta's Regional Shopping Centers*, Department of Geography Research Series No. 1, Georgia State University, 1978. \$15.00

Sanford H. Bederman, *God's Will: The Travels of Rabbi Mordochai Abi Serour*, Department of Geography Research Series No. 2, Georgia State University, 1980. \$6.00

Truman A. Hartshorn, *Charting the 1980s: Developing Strategies for Urban Georgia*, Department of Geography Research Series No. 3, Georgia State University, 1980. \$5.00

Sanford H. Bederman, *Oscar MacCarthy, Charles de Foucauld, and Geographical Exploration in North Africa: Two Essays*, Department of Geography Research Series No. 4, Georgia State University, 1983. \$4.50

Nanda R. Shrestha, *A Socioeconomic Theory of Migration: A Political Economy Perspective*, Department of Geography Research Series No. 5, Georgia State University, 1983. \$5.00

John M. Ball, *An Atlas of Nuclear Energy: A Non Technical World Portrait of Commercial Nuclear Energy*, Department of Geography Research Series No. 6, Georgia State University, 1984. \$6.00

(The above prices are for prepaid orders. For all others please add \$1.00 for handling and billing)